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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 175.

A. C. TRUE, Director.

EXPERIMENTS ON THE METABOLISM OF MATTER AND ENERGY IN THE HUMAN BODY,

1903-1904.

BY

F. G. BENEDICT, Ph. D., and R. D. MILNER, Ph. B.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

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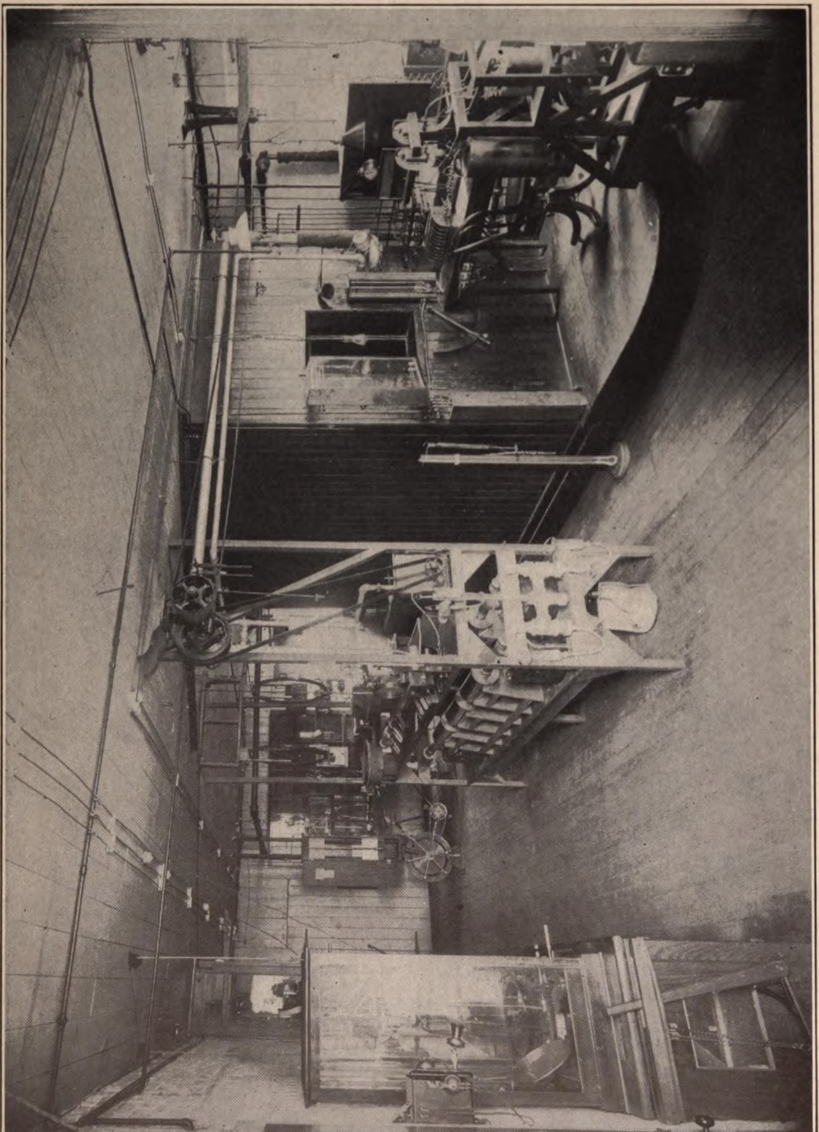

GENERAL VIEW OF THE RESPIRATION CALORIMETER LABORATORY.

941 Issued June 15, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 175.

A. C. TRUE, Director.

EXPERIMENTS ON THE METABOLISM OF MATTER AND ENERGY IN THE HUMAN BODY,

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BY

F. G. BENEDICT, Ph. D., and R. D. MILNER, Ph. B.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

THE OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., December 15, 1906.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin 175 of this Office a report of eleven experiments on the metabolism of matter and energy in the human body, by F. G. Benedict, Ph. D., professor of chemistry at Wesleyan University, expert in charge of respiration calorimeter investigations, and R. D. Milner, Ph. B., assistant in nutrition investigations.

The experiments form a part of the investigations in progress at Middletown, Conn., carried on in cooperation with Wesleyan University, for the purpose of studying the fundamental laws of nutrition and a variety of questions which depend upon them.

Like the experiments reported in previous publications of this Office, those here described furnish important data regarding the transformations of matter and energy in the body, the demands of the body for nutriment, the effect of muscular work upon such demands, and the actual nutritive values of the different kinds of food materials and their ingredients. These experiments differ materially from those previously reported, however, in that the respiration calorimeter with which they were made has undergone an important modification which permits the direct measurement of the amount of oxygen consumed by the subject, thus affording a more complete balance of income and outgo of matter and energy than has ever been possible hitherto. Preceding the account of the experiments in the present report is a description of the respiration calorimeter in its modified condition.

In addition to the other topics considered in the discussion of results, that of ventilation, which has not previously been especially treated in these experiments, has been taken up in some detail. The respiration calorimeter affords unusual opportunity to study the effect of large amounts of carbon dioxid in the air and of the vitiation of the atmosphere by respiration upon the metabolism of matter and energy in the body and upon bodily comfort, and the results of one such experiment are considered in this discussion.

Respectfully,

A. C. True, *Director.*

Hon. James Wilson,
Secretary of Agriculture.

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METABOLISM OF MATTER AND ENERGY IN THE HUMAN BODY.

INTRODUCTION.

A physiological study of the nutritive processes of man involves observations not only of chemical and thermal transformations, but also of the general condition and health of the subject of the experiment. Some of these observations, such as the grosser fluctuations in weight, the condition of appetite, and other data pertaining to general bodily health, require no special form of apparatus or refinement of method, and in experiments extending over a long period may afford valuable clews in the solving of such problems as the influence of a certain diet or article of food or method of feeding. Results more reliable and far more complete may, however, be obtained in much shorter experiments if accurate apparatus and experimental technique are employed. Thus it might take several weeks to prove by alterations in body weight that fat is being deposited in the body; but an apparatus for determining the entire income and outgo of the body will give the same information in twenty-four hours, and in quantitative terms. Hence, while with domestic animals questions of diet are usually studied by feeding experiments extending over relatively long periods, it is possible with a special apparatus to investigate problems of this nature in periods of a few days' duration. This is especially advantageous in experimenting with man. With animals the consumption of a constant diet is not irksome, and long experiments are perfectly feasible; but with man, restricted diets soon become distasteful, and the duration of the experiment is therefore much more limited.

Furthermore, in studying the transformations of matter and energy in so complicated a mechanism as the human body, knowledge regarding as many factors as possible is of prime importance. To be sure, the fluctuations in body weight, quantity of urine voided, weight and general appearance of feces, rate of respiration, body temperature, and numerous other observations of a similar nature are, even when independently observed, of considerable importance in studying the changes taking place in the body. In a simultaneous observation of all these and allied factors, however, each becomes of itself more significant and greatly increased in value. For instance, when studying the chemical and physical processes involved in the metabolism of matter and the transformations of energy, simultaneous observations of the carbon dioxid and water output and oxygen intake of the respiratory tract, the chemical nature of the food, drink, and excreta, the potential energy of the food and excreta, and the sensible heat given out from the body, give data which not only throw light on the fundamental questions of metabolism, but also render more intelligible each phase of the subject. Hence, in studying the processes of metabolism, the larger the number of factors that can be determined simultaneously the more intelligible is each series of observations.

The chief factors pertaining to the metabolism of matter in the living organism which at present can be determined with reasonable accuracy may be classed as follows:

Intake—
- Dry matter of food, including drink other than water.
- Water of food and drink.
- Oxygen from inspired air.

Output—
- Dry matter of feces and urine.
- Water of feces and urine.
- Water of respiration and perspiration.
- Carbon dioxid.

Complete analyses may be made of the dry matter of food, feces, and urine, including determinations of nitrogen, carbon, hydrogen, and mineral matters.

The factors involved in the study of the transformation of energy are:

Intake—
- Potential or chemical energy of the food and drink.
- Sensible heat of food and drink arising from the difference between the temperature of the food and that of the body, usually negative.

Output—
- Potential or chemical energy of excreta.
- Heat, including—
  - (*a*) Sensible heat of excreta.
  - (*b*) Latent heat of water vapor.
  - (*c*) Heat given off by radiation and conduction.
- Mechanical energy of external muscular work.

For the simultaneous determination of all of these factors a special form of apparatus, which is, at the same time, a respiration apparatus for the measurement of the respiratory gases, and a calorimeter for the determination of heat—that is, a so-called respiration calorimeter—is necessary. In addition certain accessory apparatus, such as a calorimetric bomb for the determination of the potential energy or heat of oxidation of food and excreta, an ergometer for measuring the mechanical equivalent of the external muscular work, and the chemical equipment incidental to a laboratory for the study of physiological chemistry, are essential.

The present publication contains a report of 11 experiments with 4 different men in which the factors enumerated above were determined by means of the different forms of apparatus just mentioned. Preceding the account of the experiments some explanation of the apparatus and experimental methods seems desirable. Following the details of the experiments is a discussion of several topics based upon the results obtained in the investigations.

DESCRIPTION OF APPARATUS AND METHODS.

The respiration calorimeter used in these experiments has been in process of development for twelve years. The earliest account[a] of its development, which was published in 1897, contained a report of four experiments with man in which the metabolism of nitrogen and carbon was measured. The appliances for measuring heat were not yet perfected sufficiently to afford satisfactory determinations of energy given off by the subject. This defect was soon remedied, and the apparatus was gradually modified and improved in many respects, and later publications[b] gave more complete descriptions of the apparatus and the various modifications, and reported a large number of experiments with different subjects in which the transformations of both matter and energy in the body were studied.

For the determination of the respiratory products, the apparatus as used in those experiments was arranged according to the well-known "open circuit" plan of Pettenkofer and Voit. It consisted of a metal-walled chamber, through which a current of air was caused to pass. Analyses of the air before it entered and after it left the chamber and the measurement of the volume of air that passed through the chamber gave data for computing the quantity of carbon dioxid and water vapor eliminated by the subject. The results obtained for water vapor were not quite so accurate as those for carbon dioxid.

The data obtained by means of this apparatus, however, were not sufficiently complete for proper estimation of the transformations of matter that may occur in the body. In interpreting the data of the experiments it was assumed that there were no changes in the quantity of glycogen stored in the body, and the carbon dioxid given off was treated as if derived only from the disintegration of protein and fat. From the quantity of nitrogen in the urine the amount of protein katabolized was computed, and the carbon pertaining to this protein was ascertained from the elementary composition of animal protein. The remaining carbon in the carbon dioxid eliminated was then supposed to be derived entirely from fat, according to the above-mentioned assumption that the amount of glycogen in the liver and muscles remains practically constant.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 44.

[b] U. S. Dept. Agr., Office of Experiment Stations Buls. 63, 69, 106, and 136.

That such an interpretation of the data is correct is very much to be doubted, especially when there are wide variations in the nature or quantity of food ingested. Particularly would this be the case during fasting. Recent physiological researches indicate that muscular energy is in large measure, if not wholly, derived from the disintegration of carbohydrate material. Data regarding the transformations of carbohydrates in the body are therefore very desirable.

Such data could not be obtained by use of the form of apparatus above mentioned, for the reason that it did not afford means for determining the amount of oxygen consumed. In order to distinguish between the carbon due to the transformation of fat and that due to the transformation of carbohydrates, it is necessary to have accurate data regarding the intake of oxygen, and the ratio between the oxygen consumed and the carbon dioxid eliminated; in other words, the so-called respiratory quotient. An attempt was made[a] to estimate (by difference) the amounts of oxygen consumed in some of the experiments, but this was considered much less satisfactory than actual determinations.

No satisfactory method was found for determining the amount of oxygen consumed by a subject in a respiration calorimeter of the sort mentioned above, that is, with an " open-circuit " respiration apparatus.[b] Plans had been gradually evolved, however, for changing the form of apparatus in such a manner as to make possible the determination of the amount of oxygen consumed. It was desired to maintain in this modified form of apparatus the accuracy of the carbon dioxid determination with the earlier form and to increase, if possible, the accuracy of the water determination.

The year 1902–3 was mainly occupied in developing such a form of apparatus. Considerable modification was involved and several new accessory devices were necessary. The expenses attending the addition of this new feature of the apparatus were defrayed by grants from the Carnegie Institution of Washington. A detailed description of the respiration apparatus in its modified form and also of the calorimeter, which has likewise been very much improved in recent years, is given in a recent publication of the Carnegie Institution.[a] In the present bulletin, therefore, only a summary account of the respiration calorimeter will be given. The details may be found in the Carnegie Institution report mentioned. The purpose here is simply to give such explanation as is needed for a proper understanding of the investigations reported beyond.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 163.

[b] It should be here noted that Jaquet has devised a respiration apparatus of the open-circuit type, devoid, however, of calorimetric features, in which the oxygen used by the subject is computed from direct determinations of oxygen in the air entering and leaving the chamber. (Verhandl. Naturf. Gesell. Basel, 15 (1904), pt. 2, p. 252.)

ARRANGEMENT OF APPARATUS IN THE LABORATORY.

The laboratory is located in the basement of a building occupied by the chemical department of Wesleyan University, at Middletown, Conn. The room is that in which the old form of apparatus was installed, as shown in preceding publications,[b] but the addition of appliances for measuring oxygen have necessitated changes in the disposition of the various parts. A general view of the laboratory is shown in the frontispiece and the general plan is given in figure 1.

The respiration chamber is placed a little to the north of the middle of the room, and on the south side of it is the apparatus for purifying the air and determining the amount of carbon dioxid and water vapor in it. In the east end of the chamber is the large opening that serves as door and window, and just in front of this is a table, at which observers sit during the whole of an experiment. The table is placed here chiefly for convenience in noting the movements of the subject, through the window. On the observer's table are all the appliances for determining and controlling the temperature of the calorimeter. Opposite the table is the water meter for determining the quantity of water that passes through the heat absorber within the chamber.

The rotary blower used for maintaining the ventilating current of air is actuated by power from an electric motor which drives the line shaft running along the ceiling at the north side of the room. By means of a countershaft the blower may be stopped or started at will. In one corner of the room are storage batteries used in connection with certain electrical devices. Balances and other accessory apparatus are arranged along the walls of the laboratory.

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[a] Carnegie Inst. Washington Pub. No. 42.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 136. Frontispiece and p. 13.

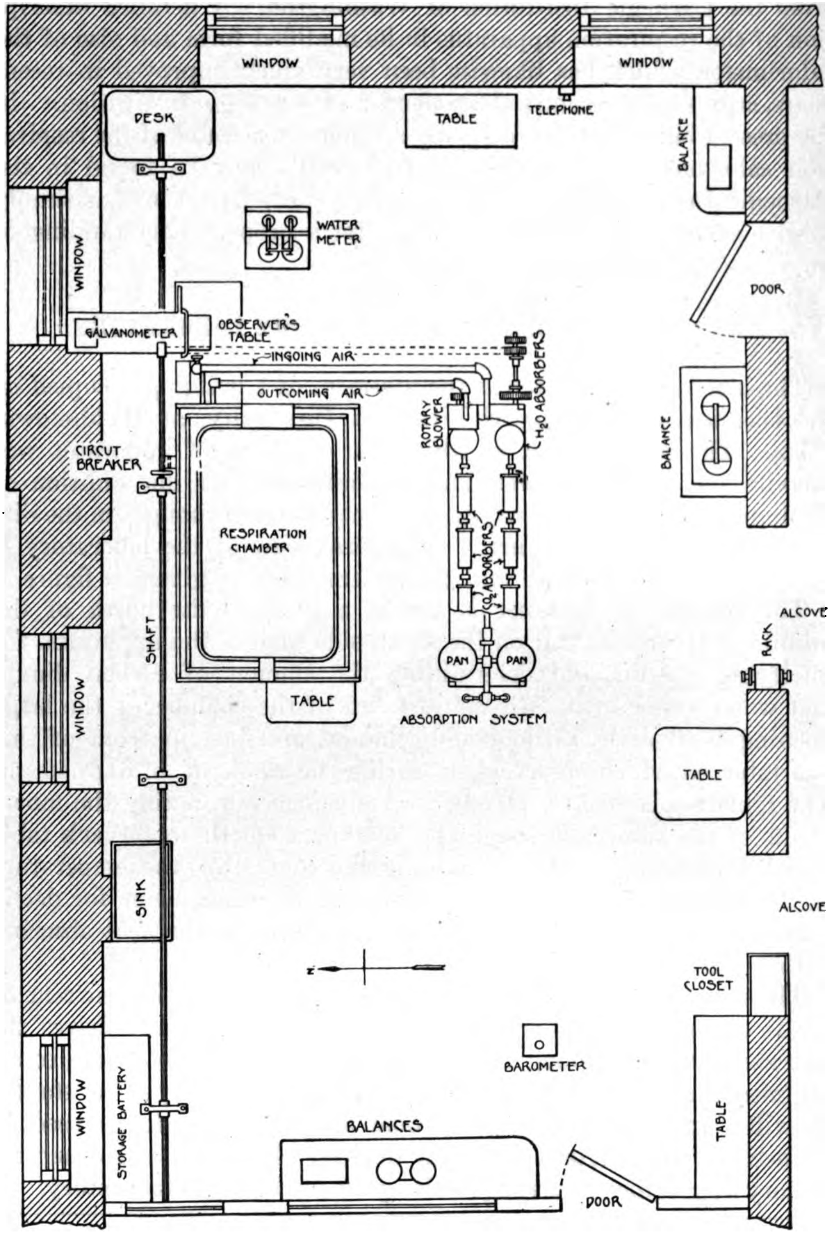

Fig. 1.—Diagram of respiration calorimeter laboratory.

THE RESPIRATION APPARATUS.

The respiration apparatus in its present form is in principle essentially the same as that of Regnault and Reiset,[a] that is, a so-called "closed-circuit" respiration apparatus. The same current of air is kept in circulation through the chamber, the carbon dioxid and water vapor imparted to it by the subject being removed as it is withdrawn from the chamber and oxygen restored to it as it is returned to the chamber. The quantities of carbon dioxid and water removed from the air and of oxygen supplied are ascertained as explained beyond.

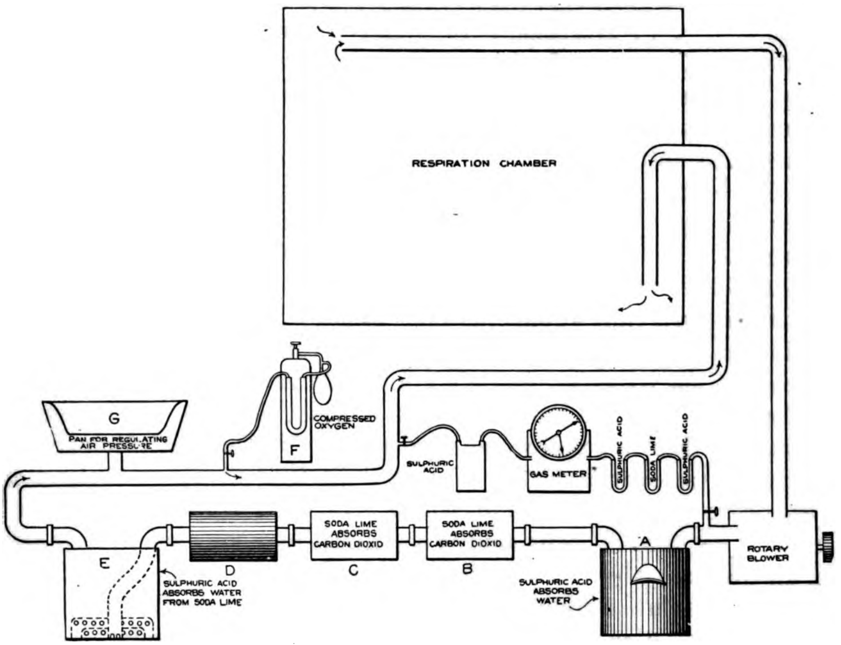
RESPIRATION CHAMBER
G
PAN FOR REGULATING AIR PRESSURE
COMPRESSED OXYGEN
F
SULPHURIC ACID
GAS METER
SULPHURIC ACID
SODA LIME
SULPHURIC ACID
E
SULPHURIC ACID ABSORBS WATER FROM SODA LIME
D
SODA LIME ABSORBS CARBON DIOXID
C
SODA LIME ABSORBS CARBON DIOXID
B
A
SULPHURIC ACID ABSORBS WATER
ROTARY BLOWER

FIG. 2.—Schematic outline of the respiration system.

The details of the respiration apparatus were not exactly the same in all of the investigations reported in the present publication. During the period in which they were conducted, various accessory devices were developed and improved to increase the facility of manipulation or the accuracy of the results obtained. In consequence, the apparatus was in much better condition for the last experiments than for the first. The fundamental principle of the apparatus, however, which is illustrated by figure 2, was the same in all the experiments.

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[a] Ann. Chim. et Phys., 3 (1849), p. 26.

At the beginning of an experiment there is in the respiration chamber air containing oxygen, nitrogen, carbon dioxid, and water vapor, as in an ordinary room.. With the entrance of the subject there is immediately a consumption of oxygen and an elimination of carbon dioxid and water vapor. The air is withdrawn from the chamber, passed through absorbents for the removal of the respiratory products, oxygen is added to replace that used by the subject, and it is again returned to the chamber.

To maintain a current of air for ventilation and to cause it to pass through the absorbents for removing water vapor and carbon dioxid, it is necessary to overcome a resistance equivalent to a pressure of about 40 millimeters of mercury. In several of the experiments a pump [a] was used for this purpose, which was connected in such a way as to produce a slightly diminished pressure, and thus draw the air through the absorbing system. This method was found unsatisfactory, however, and later the pump was replaced by a small rotary blower giving a positive pressure and forcing the air through the absorbents. By means of this blower a current of air flowing at the rate of 75 liters a minute is maintained.

The air-purifying apparatus must remove from a current of air, flowing at the above rate, all the water vapor and carbon dioxid, which in some experiments may amount to as much as 50 grams of the former and 125 to 150 grams of the latter per hour. The absorbers used in these investigations accomplish this very satisfactorily.

For the removal of water vapor the air that leaves the blower is passed through sulphuric acid, which is one of the best absorbents of water vapor known. The acid is contained in a stoneware receptacle (*A* in diagram above) so designed that the air is caused to pass in small bubbles up through a layer of acid several centimeters deep, thus affording opportunity for complete absorption of water. It has been found that an absorber of this type containing about 3.5 liters of strong sulphuric acid (specific gravity 1.84) will remove 500 grams of water vapor from the air current flowing at the above-mentioned rate before allowing any to pass by.

The air leaving the acid receptacle is perfectly dry, but still contains carbon dioxid. To remove this, it is next passed through soda lime (a mixture of caustic soda and quicklime). This reagent is contained in three brass cylinders (*B*, *C*, and *D* in the diagram) that are silver plated to resist the action of the alkalis. These absorbers equally as efficient as the one for water vapor, and the soda lime in each one will, under ordinary conditions, remove 400 grams of carbon dioxid from the air current.

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[a] U. S. Dept. Agr., Yearbook 1904, p. 209.

The soda lime in these absorbers is somewhat damp, as it has been found to be most efficient when in that condition. The dry air from the sulphuric acid takes up some of this moisture, which must be removed; consequently the air is next passed through another jar of sulphuric acid (*E*) like the first.

The air leaving the last water absorber is dry and free from carbon dioxid, but deficient in oxygen by the amount used by the subject. Oxygen is therefore admitted from a steel cylinder (*F*), in which it is contained under pressure, into the pipe by which the air is returned to the respiration chamber.

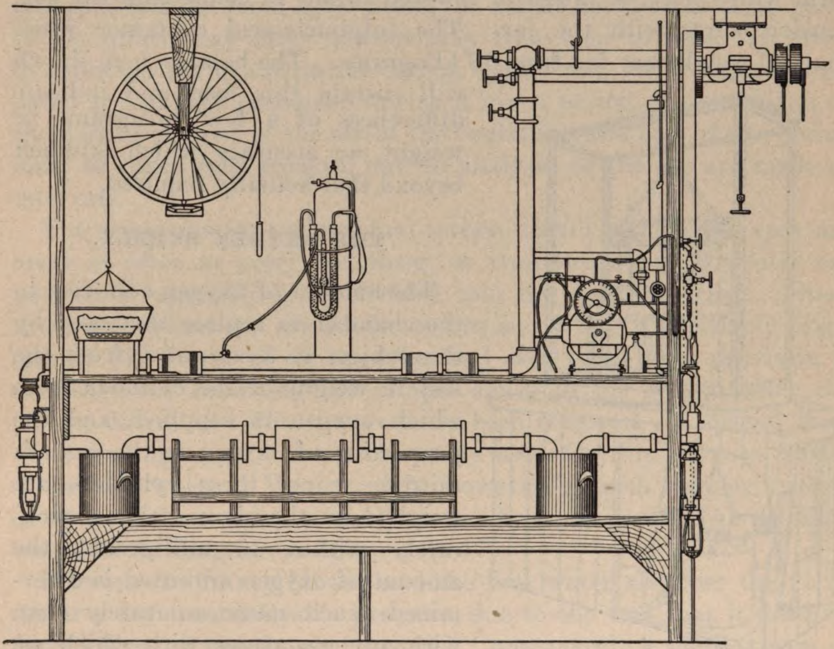

FIG. 3.—Arrangement of the devices for purifying the circulating air.

The removal of the respiratory products from the air, and changes in thermometric conditions within the chamber and in barometric pressure without, cause differences in the volume of air within the system. In order that the air in the chamber may be kept at normal pressure under all conditions, two pans (*G*) with flexible rubber diaphragms are connected with the ingoing air pipe and serve as pressure equalizers.

The devices above referred to are arranged as shown in figure 3.

WEIGHING THE ABSORBERS.

The amounts of water vapor and carbon dioxid removed from the air are determined by weighing the absorbers. For this purpose the balance shown in figure 4 was employed.

This balance is mounted on a shelf that is firmly attached to the brick wall of the laboratory. Provision is made for suspending either kind of absorber from one end of the beam. The figure shows a sulphuric-acid jar about to be suspended, resting on a swing platform which may be raised or lowered to aid in connecting the suspension wires with the jar. The sulphuric-acid container when charged weighs not far from 18 kilograms. The balance here shown will sustain this load and indicate differences of a few milligrams in weight, an accuracy which is much beyond that actually required.

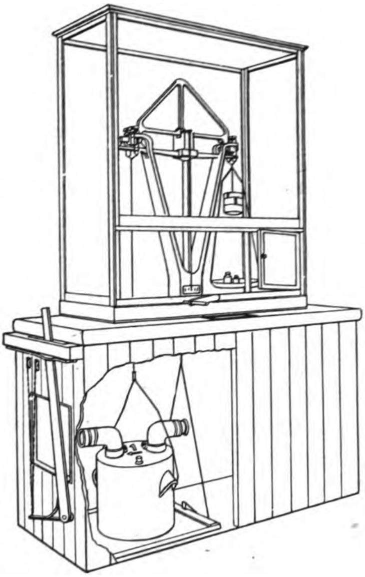

FIG. 4.—Diagram of the balance for weighing the absorbers and oxygen cylinders.

THE OXYGEN SUPPLY.

The amount of oxygen admitted to the chamber to replace that used by the subject is ascertained from the loss in weight of the cylinder from which oxygen is supplied, and the proportion of oxygen in the gas admitted. Since these cylinders are weighed on the above balance accurately within 10 milligrams, the amount of oxygen admitted is determined much more accurately than with any gas meter with which we are familiar.

In addition to the oxygen, the cylinders contain 2.5 to 8 per cent of nitrogen and a small proportion of carbon dioxid and water vapor. The two latter are removed before the oxygen is admitted to the air current, by passing the gas through a U tube containing sulphuric acid and soda lime. Such a tube is always attached to the cylinder when in use, and always weighed with it, so that there is no necessity of knowing how much of these gases are present. Inasmuch as the nitrogen is admitted with the oxygen, however, the percentage of nitrogen in each cylinder is ascertained. The proportion of oxygen in the mixture that passes the U tube is determined by absorption with potassium pyrogallate, and the remainder is taken as nitrogen.

Since nitrogen is thus admitted with the oxygen supplied to replace that used by the subject, and only the oxygen is actually consumed, it is apparent that nitrogen would tend to accumulate in the system. To reduce the quantity of nitrogen present, a definite volume of air is withdrawn from the system at certain intervals and oxygen is supplied to restore the volume.

ANALYSIS OF RESIDUAL AIR.

The proportions of carbon dioxid, water vapor, and oxygen in the air are constantly changing, and since the total volume of air in the system is not far from 5,000 liters, the actual amounts of these gases in the system may differ considerably from time to time. In order to ascertain the quantities of carbon dioxid and water vapor eliminated and oxygen consumed during a given period, the quantities of these gases present in the air at the beginning and end of the period must be taken into account, and so analyses of the air are made at intervals.

The determinations of residual carbon dioxid and water vapor are made as often as every six, three, or even two hours, the later experiments especially being divided into the shorter periods. Since these determinations are made so frequently and a relatively large sample (10 liters) of air must be used each time, some provision is necessary for returning the sample again to the system after the carbon dioxid and water vapor have been removed. A special form of aspirating apparatus was formerly used for this purpose, as described elsewhere.[a] Very recently, however, a much simpler method of making these residual analyses has been adopted. This is illustrated in the diagram in figure 2 (p. 17).

Between the rotary blower and the first water absorber the air is under a not inconsiderable pressure, due to the fact that it must be forced through the absorber system. Consequently a small stream of air may be diverted through an opening in the air pipe at this point, sent through apparatus for purifying and measuring it, and returned again to the system through an opening in the ingoing air pipe, without materially decreasing the pressure necessary to force the main current of air through the large absorbers.

The tube from the opening in the pipe near the blower is connected first with a mercury trap by which a small current of air may be started or stopped at will. When the trap is open the air passes first through a U tube containing sulphuric acid to remove the water vapor, next through a second U tube containing soda lime to remove carbon dioxid, and finally through a third U tube containing sulphuric acid to catch the water vapor that the dry air takes from the moist soda lime. The air then enters an Elster meter, which has been carefully calibrated as described by one of us,[a] to measure the volume of the sample, then through a bottle of sulphuric acid to remove water vapor taken up in passing through the meter, and finally returns to the main air pipe dry and free from carbon dioxid.

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[a] Carnegie Inst. Washington Pub. No. 42, p. 48.

The proportions of carbon dioxid and water vapor in the air are ascertained from the volume of the sample and the increase in weight of the U tubes.

The operation of taking the sample is very simple. The meter is read, the mercury trap lowered, and air allowed to pass through the U tubes, the meter, and the drying bottle back to the main air pipe. With the pressure usually obtained, the air is passed through the meter at the rate of about 3 liters per minute. When approximately 10 liters have passed through the meter the mercury trap is raised, thus stopping the current, and after the meter has come to rest its pointer is read. The pressure of the gas in the meter is accurately determined by means of a water manometer, which, since the pressure at the blower is very constant, remains at practically the same position during the entire process of taking the sample. When about half of the desired sample is taken—i. e., when 5 liters have passed through the meter—the position of the manometer and the temperature of the meter are recorded. The whole operation is then repeated for a duplicate analysis, the time of taking the samples being so adjusted that the last portion of the second sample will have been taken a few seconds before the end of an experimental period.

Actual determination of the amount of oxygen residual in the air of the system is made only once in twenty-four hours, usually at 7 a. m. A sufficiently large sample of air is withdrawn from the chamber at that time, and the proportion of oxygen in it is determined by the method of absorption by potassium pyrogallate previously mentioned. Since the quantities of oxygen and nitrogen admitted to the system each period are known, however, from the loss in weight of the oxygen cylinder during the period and the proportions of oxygen and nitrogen in it as shown by previous analysis, it is possible to compute the residual oxygen for each period as readily as if analysis of the air were made. The factors for such computation are as follows: (1) The total volume of air in the system, i. e., the apparent volume reduced to standard conditions according to records of temperature and barometric pressure; (2) the quantities of carbon dioxid and water vapor present, as shown by analysis; (3) the quantity of nitrogen present, including the total ascertained by analysis at the beginning of the day, and that added with the oxygen. The sum of these quantities of carbon dioxid, water vapor, and nitrogen subtracted from the total quantity of air gives the quantity of oxygen present.

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[a] Phys. Rev., 22 (1906), p. 294.

The accuracy of such computations depends upon the absence of leakage of air into or out of the system. The analysis at the beginning of each day serves as a check upon such computations for the preceding day. When there are no leaks the results obtained by computation are practically identical with those by analysis. Indeed, so close an agreement has been regularly found under such conditions that a discrepancy between the computed and determined results is now considered an absolute indication of leakage, and the observed differences are taken as data for which allowance must be made to obtain correct results.

DETERMINATION OF THE QUANTITIES OF WATER VAPOR AND CARBON DIOXID ELIMINATED AND OXYGEN CONSUMED.

The increase in the weight of the first water absorber is the amount of water vapor removed from the ventilating air current, but this does not represent the total amount eliminated by the subject. Allowance must be made, as already stated, for changes in the quantity of water vapor residual in the air system, and also for the small amount removed by analyzing the sample of residual air. Moreover, certain articles within the respiration chamber, such as the clothing of the subject, the bedclothing, the wooden chair, books, etc., may absorb or give off moisture according to the hygroscopic conditions. Accordingly allowance must also be made for gains or losses in weight of such materials. Furthermore, whenever the temperature of the water in the heat-absorbing device is below the dew-point of the air within the chamber, moisture is precipitated from the air upon the heat absorber and collected as drip. The weight of water thus collected must of course be added to the quantity just mentioned. The amount of water vapor actually eliminated by the subject is ascertained from all these data.

The quantity of carbon dioxid removed from the air current is determined from the gain in weight of the three soda-lime cylinders and the second sulphuric-acid jar. The latter must be taken into account, because the moisture it absorbs comes from the soda lime. It happens not infrequently that the reagent in the first cylinder becomes so exhausted that the weight of water it loses is greater than that of the carbon dioxid it absorbs. The algebraic sum of the gains and losses of weight by these four absorbers, therefore, gives the amount of carbon dioxid absorbed from the air current. To determine the total quantity actually given off by the subject, however, allowance must be made for the change in the amount residual in the air, the quantity removed from the air current in analyzing the residual sample, and in some instances the small quantity mentioned below in the consideration of possible errors in determination.

The amount of oxygen admitted to the system is determined from the loss in weight of the cylinder from which it is supplied and the percentage of oxygen in the gas in the cylinder as found by analysis. To determine the amount actually consumed allowance must of course be made for the oxygen remaining in the air of the system.

POSSIBILITIES OF ERROR IN THE ABOVE DETERMINATIONS.

Although the quantities of carbon dioxid and water vapor given off and of oxygen consumed by the subject are ascertained in the manner above described, it is probable that some small corrections should be made in the above data for greater accuracy. It seems desirable to mention here the possible sources of error and to consider their probable effect upon the results.

INTERCHANGE OF AIR THROUGH THE FOOD APERTURE.

The food aperture has an air-tight closure at each end, permitting the exchange of articles between the laboratory and the respiration chamber. It is assumed that when the outer door is open and the inner door closed the air in the aperture has the same composition as that of the laboratory, and that when the outer door is closed and the inner one open the composition is that of the air within the chamber; though it is doubtful if diffusion is so rapid as to cause such a change of composition of the air in the aperture during the short time either door is ever kept open. On the other hand, when articles are transmitted between the laboratory and the respiration chamber through the aperture there is a displacement of air according to the volume of the article placed in the aperture, and in this way there is opportunity for air from the chamber to be brought out or air from the laboratory to be admitted. From the volume of the articles sent in or out and the record of their passage back and forth through the aperture an estimate can be made of the amount of air passing in either direction and of the quantity of the different gases thus moved into or out of the respiration chamber.

In the case of water vapor the differences in relative humidity of the air within and that without the chamber are usually so small that the error involved in neglecting the quantity of water vapor in such interchange of air is infinitesimal.

Under ordinary experimental conditions the amount of carbon dioxid involved is rarely sufficient to make an appreciable error if neglected. Under other conditions, however, for example, in work experiments, when the carbon dioxid production is large or in experiments in which this gas is purposely allowed to accumulate within the chamber, the displacement of all the air in the food aperture (4.5 liters) might result in the escape of as much as 0.02 gram of carbon dioxid. Because the percentage of carbon dioxid in the air of the chamber is so much larger than that in the air of the laboratory, the interchange of air always results in a loss of this gas. The total amount that actually does escape in this way is so small, however, in comparison with that in the chamber under the conditions mentioned, that the percentage error resulting from neglecting such loss entirely would be inappreciable. When it seems necessary, an allowance can be made for the amount of carbon dioxid thus lost, but it is simply an estimate, as it is not actually determined.

A slight error in the oxygen determination is also involved in the interchange of air through the food aperature. This may be either a gain or a loss, according to the difference in the percentage of oxygen in the air within and without the chamber. As in the case of carbon dioxid, an estimate of the amount gained or lost can be made when necessary, but it is usually so small as to be proportionately inappreciable.

AIR REMAINING IN THE ABSORBERS.

When the first water absorber is removed for weighing at the end of each period, the air above the acid still contains carbon dioxid. Since the air outlet of the absorber is open during the weighing, there is opportunity for diffusion, and carbon dioxid may escape, though it is doubtful if much does escape in this way. When the absorber is finally removed to change the acid, however, it is likely that the carbon dioxid remaining at that time is lost. The volume of air in the absorber is known, and the proportion of carbon dioxid present is also known, because the residual analysis is made just before the absorber is removed; hence a definite allowance can be made for the quantity of carbon dioxid lost in this way.

It is assumed that the air in the soda-lime cylinders and in the second water absorber is free from carbon dioxid, and that therefore none of this gas is lost when these absorbers are removed. The air in all the absorbers, including both these and the first water absorber, usually contains a smaller proportion of oxygen than that present in the air of the laboratory, and there is therefore opportunity for the acquisition of oxygen from the air of the laboratory by diffusion, but probably little is thus acquired. When the absorbers are again connected in the system air is forced into them under pressure to test for leakage, and some of this of course replaces the air present in the absorbers when they were removed, and thus changes the proportions of the gases present. Furthermore, when the reagents in the absorbers are exhausted and removed and fresh reagents supplied, the air in the absorbers is entirely replaced by ordinary air. Since, as stated above, the proportion of oxygen in the air removed in the absorbers is smaller than that of ordinary air, there would be an addition of oxygen to the system by the change of absorbers. The quantity of oxygen thus introduced may be estimated and allowance made for it.

COMPOSITION OF THE SAMPLE OF RESIDUAL AIR.

It is assumed that the residual air analyzed at the end of each period is a fair sample of the total air in the respiration chamber. Since the air entering the chamber is free from carbon dioxid and water vapor, and that leaving it contains both, there is unquestionably an area about the outlet of the ingoing air pipe in which the percentage of carbon dioxid and water vapor is much lower than in other parts of the chamber. Furthermore, the air leaving the chamber is deficient in oxygen, whereas that entering the chamber contains the oxygen supplied to make good this deficiency; hence there is also a difference in the proportion of oxygen in the regions mentioned. Moreover, the air enveloping the body of the subject becomes warm and rises, so that there is a stratification of the air with possible differences in composition of different strata. This is the basis of a criticism by Heymann[a] on the research of Wolpert on the effect of carbon dioxid in the air on the total carbon dioxid elimination through the lungs. Heymann takes exception to Wolpert's assumption that the composition of the air drawn from any point in the closed box represents the average composition of the total.

As a matter of fact, the analyses obtained by Wolpert were used in such a manner that the error involved would have a maximum effect, whereas in the use of the analyses of the residual air in the investigations here reported such an error is much less significant. In Wolpert's apparatus there was no movement of the air; in this apparatus there is a circulation of 75 liters per minute. Furthermore, the absolute variations in the quantities of the carbon dioxid residual in the chamber are of much less importance in our computations than the relative changes, and in the determinations made with the respiration calorimeter it is assumed that fluctuations in the composition of the air in the outgoing air pipe are parallel to the fluctuations in composition of the large mass of air within the respiration chamber. At present there is no simple method of obtaining samples of the air in such a way as to eliminate this assumption. That the possible error can in any wise seriously influence the results is very much to be doubted.

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[a] Ztschr. Hyg. u. Infectionskrank., 49 (1905), p. 390.

CALCULATIONS OF THE AMOUNTS OF RESIDUAL GASES.

To calculate the quantities of gases residual in the chamber, the values obtained in the analyses of the sample of residual air must be multiplied by a rather large factor, corresponding to the ratio between the volume of air taken for a sample and the total volume of air residual in the chamber. The computation of this total volume depends upon several factors: (1) Measurements of apparent volume, which are definite; (2) corrections for alterations in volume due to the passage of objects into or out of the chamber, which can be computed with considerable accuracy; (3) variations in barometric pressure, which can be obtained with an accurate barometer to the thousandths of an inch, and (4) the average temperature of the air within the chamber, which as yet is difficult to ascertain with the desired accuracy.

In calculating the total volume of air it is assumed that the temperature of the air is not far from uniform in all parts of the chamber and that the average temperature of the air is ascertained by use of the electric resistance thermometers (see p. 29). Neither of these assumptions is strictly correct, as is shown by the discussion of the thermal gradient given beyond.

Any error in the last factor above mentioned affects the calculation of the amounts of all the residual gases, though in the case of water vapor the effect is small, since the total amount present is seldom over 70 or 80 grams. The error in the case of carbon dioxid would be somewhat larger, as the total amount present may at times be 180 grams. In the case of the oxygen, however, of which from 1,200 to 1,400 grams may be present, a very small error in the temperature measurement would have a relatively large effect on the results of the calculations.

HYGROMETRIC CONDITIONS WITHIN THE CHAMBER.

In experiments with the respiration apparatus serious difficulty has been experienced in obtaining satisfactory determinations of water; but by eliminating as far as possible all known sources of error this difficulty has been gradually overcome, until at the present time very satisfactory results can be obtained, as shown by the data of test experiments given beyond (p. 40). The chief difficulty now is in apparent changes in the hygrometric condition of objects within the chamber. Metal surfaces are usually considered nearly devoid of any degree of hygroscopy, and every effort is made to avoid all fixtures other than those of metal inside the chamber, but it is evident that even these impart moisture to dry air. For example, in an experiment in which the accuracy of the apparatus is tested by combustion of alcohol within the chamber (see p. 44), the amount of water produced is so small that the amount of residual water vapor decreases and the atmosphere becomes drier. Under these conditions water seems to be given off by the walls of the chamber and other metal surfaces, as the quantity of water absorbed from the air current is larger than should be obtained from the combustion of the known quantity of alcohol. It is usually some hours after the experiment begins before the walls are so dry that they will no longer yield water to the dry air.

When a man is in the chamber the degree of humidity of the air is not nearly as low; still it is possible that even then moisture is derived from the metal surfaces. Some is certainly absorbed from books, bedding, and clothing of the subject, the amount of which is ascertained by actual weighing of these objects, as already explained. The technique of the determination of loss of water by the contents of the chamber other than metal fixtures has been so perfected that an accurate correction for the water vapor from this source is now obtained, and it is believed that no great error is introduced by assuming that the hygrometric conditions of the metal surfaces are the same at the end of the experiment as at the beginning.

IMPURITIES IN THE COMPRESSED OXYGEN.

The gases in the cylinder from which oxygen is supplied to the system are passed first through soda lime and sulphuric acid to remove carbon dioxid and water vapor. It is assumed that only oxygen and nitrogen remain, and that in the analysis all that is not absorbed by potassium hydroxid or postassium pyrogallate is nitrogen. By the results of these analyses the quantities of oxygen and nitrogen admitted to the system are computed. There is reason for believing that there are small amounts of volatile hydrocarbons which possibly escape absorption in the sulphuric acid tube used to dry the oxygen, but they are so small that as yet no correction has been made for them.

THERMAL GRADIENT WITHIN THE CHAMBER.

It is explained above that in calculating the total volume of the air residual within the system, it is assumed that the temperature of the air is not far from uniform in all parts of the respiration chamber, and that the electrical resistance thermometers give the average temperature of the air, but that neither assumption is believed to be correct. When there is no source of heat within the apparatus, it is possible by means of the heating and cooling devices to keep the walls of the chamber at constant temperature for hours at a time; yet even under these conditions it is by no means certain that the temperature of the air is uniform in all parts of the chamber. If it were possible to determine the average temperature correctly, that would be satisfactory for the calculations.

Changes in the temperature of the air are determined electrically by variation in resistance of coils of copper wire due to differences in heating. Five such coils are distributed in various parts of the apparatus, each of which is affected by the temperature of the air surrounding it, and in former experiments, when oxygen was not determined, it has been sufficiently accurate to assume that the average variation of the five coils taken as a whole will closely approximate the average fluctuations of the temperature of the air within the chamber. But in experiments with the present form of apparatus, in which the oxygen is determined, the proportion of oxygen present in the air is so large, as previously stated, that accurate determinations of the temperature are needed, for which the present method of determining temperature variations of the air in the chamber seems unsatisfactory.

When heat is produced in the chamber by means of an electric resistance coil, the temperature in different regions ranges from about 100° C., that of the coil, to 8° or 9°, that of the water entering the heat absorbers; and in tests of the apparatus by the combustion of alcohol the range is much wider, the temperature of the alcohol flame being 1,500°. By regulating the absorption of heat, an attempt is made to keep what is supposed to be the average temperature of the air at 20°. The air in the immediate vicinity of the source of heat is therefore much warmer and more rarified than the average, and that in close proximity to the heat absorber is somewhat cooler and more dense. In both cases, however, the area in which the air is above the average is much less than that in which it is below it, and as the cold air falls and the warm air rises, the temperature would become more equalized. Since in both cases the sources of heat are fixed and the rate of evolution of heat is constant, and, furthermore, the rate of absorption is kept fairly uniform, the fluctuations in temperature (and consequently in apparent volume) of the air are very much reduced.

With a man inside the chamber, on the other hand, the possibility of temperature equilibrium is least, for not only is the area of high temperature very much greater, but the rate of evolution of heat from the man may range from 60 to 80 calories per hour during sleep to above 600 calories per hour in a work experiment. If the man were always in one position and did not exercise, the rate of evolution of heat would be fairly constant, and in spite of the large area of heat radiation the difficulties in obtaining the average temperature of the air inside the chamber would not be insurmountable. Such conditions practically exist at night after the man has gone to bed, as his body is then covered with the bedclothing and the heat emission is fairly constant.

In spite of the wide distribution of the electrical resistance thermometers used for observing the temperature of the air, it is doubtful whether, under even these most favorable circumstances, they do indicate the true temperature conditions with the accuracy to be desired. It is certain that they do not when the man is not in bed, and especially when he is at hard work.

By changes in clothing, by alterations in the confined volumes of air between clothing and skin, and by the absorption or emission of heat by other objects in the chamber, especially the chair, bed, bedding, etc., there are produced fluctuations in the heat emission other than those actually arising from the muscular activity of the subject. In addition to these minor fluctuations, there are great differences in heat evolution resulting from variations in muscular activity, so that the presence of the subject means a continually varying source of heat. On the other hand, in order to bring away the heat as fast as it is generated, it becomes necessary to alter the heat-absorbing capacity of the cooling system by passing in colder water, by increasing the rate of flow of water through the system, or by lowering the shields surrounding the heat absorbers and thus increasing their area. There is therefore a corresponding fluctuation in the temperature of the air in the vicinity of the heat absorbers, a temperature always lower than that of the room, tending to contract the air and thus apparently counteracting or compensating for the apparent increase in volume resulting from the increased temperature of the air about the body of the man.

Unfortunately, the difficulties in experimenting to ascertain how far these two tendencies do counteract each other are such that little has been determined regarding their resultant effect. There is little doubt, however, that there are differences in temperature of the air that are not measured accurately by the electric thermometers. Consequently there is an error in assuming that the temperature differences as determined by these thermometers are differences in average temperature of the air, and accordingly the computations of the volume of air depending on this factor contain a corresponding error.

A partial check on the electrical thermometers is obtained by observations of the position of the rubber diaphragms on the pans for equalizing pressure of the air in the system. With the present form of closed circuit the respiration chamber proper is practically the bulb of an enormous air thermometer. Since the whole system is at atmospheric pressure the changes in volume produced by changes in temperature inside the bulb are all indicated by the position of the rubber diaphragms. If, during the progress of an experimental period, the volume of oxygen admitted is exactly equal to the volume of the carbon dioxid and water vapor absorbed the position of the diaphragms will remain constant, provided there are no changes in temperature or pressure. The oxygen is seldom admitted, however, with such regularity, but is usually introduced intermittently. When the pans have been filled nearly to the top by admitting oxygen and the supply is then cut off, there should be normally a gradual diminution in the volume of air in the pans corresponding to the volume of carbon dioxid and water vapor absorbed. This will be evident by a gradual settling of the rubber diaphragms. But if there is a sudden increase in the evolution of heat inside the apparatus the rubber diaphragm will cease to fall and will even begin to rise, owing to expansion of the air. This change may actually take place some moments before an increase in temperature is recorded by the electrical resistance thermometer, thus showing that the air thermometer, consisting of the chamber and pans, is very much more sensitive than the resistance theremometers. Similarly, if the subject is riding the ergometer and suddenly stops work, there will be a cooling effect and the diaphragms will rapidly fall.

Not only will sudden fluctuations in the heat evolution produce this rise and fall in the diaphragm, but similar changes in the rate of heat absorption will also produce corresponding results. As the heat absorption is retarded by raising the shields, the diaphragms rise, and if the heat absorption is increased by lowering the shields, they fall.

Attempts have been made to secure, if possible, either a more even temperature throughout the chamber or a more accurate measurement of average temperature. In one series of experiments a small electric fan was suspended from the ceiling of the chamber in such a way as to force the air downward. The experimental work with this fan, however, was of short duration. There is a distinct disadvantage in complicating the apparatus by its use. Correction must be made for the amount of heat generated by the motor, for which purpose accurate measurement of the electric current used must be obtained. When the city circuit is used to run the motor, the measurements must be made very frequently because of fluctuations in the voltage.

The ordinary conditions within the chamber are perhaps best in this respect, since the cold air in falling through the distance to the floor becomes warm and the temperature of a considerable portion of the air thereby equalized. However, the body of the man, especially when riding the ergometer, is much nearer the top of the chamber than the bottom, and heated air from the body rises to the copper ceiling. Owing to the regulation of the temperature of the ceiling, loss of heat is prevented, but it is obvious that the air will not be equally heated under these conditions.

The problem of obtaining the average temperature of the air in the chamber is therefore a serious one. The redistribution of the electrical thermometers could hardly do more than give the average temperature of another portion of the air. An electric thermometer extending in a straight line from the bottom to the top of the chamber and thus measuring the average vertical gradient has been considered, but the location of this thermometer, in a large measure, decides its average temperature. Obviously, it must not be placed too close to the cold air about the heat absorbers nor too near the heat from the body of the subject.

By means of several electric fans the air could perhaps be kept in motion in so many different directions that the temperature would be equalized so that the electrical thermometers would give a very close approximation to the true average temperature. A serious objection to the use of fans has been mentioned above, however, and, furthermore, it would be extremely uncomfortable, if not somewhat dangerous, for the subject to be exposed to strong blasts of air.

Since the muscular activity and bodily position of the subject are the same at 7 a. m. each day, when the sample of air is taken for oxygen analysis, it is highly probable that the errors in oxygen determination, due to uncertainty in the temperature measurements of the residual air, are not appreciable at the end of an experimental period of twenty-four hours. The maximum error occurs in short experimental periods, with greatest differences in muscular activity at the beginning and end of the periods. During rest experiments those following 7 a. m. and 11 p. m. are most affected. In work experiments the periods in which the bodily activity of the subject varies at the end from that at the beginning are most liable to error in the measurement of the average temperature of the air in the chamber. For all periods with like muscular activity at the beginning and at the end the error may be considered negligible.

THE CALORIMETER.

It has been stated (p. 13) that the device employed in these investigations combines a respiratory apparatus and a calorimeter in the same construction, and the determination of the heat output of the subject is made concurrently with the measurements of the respiratory products and oxygen. The apparatus is so devised and manipulated that the passage of heat through the walls of the chamber is prevented, and the heat evolved by the subject can not escape in any other way than that provided for carrying it out and measuring it. A small quantity leaves the chamber as latent heat of water vapor, but the major portion is sensible heat absorbed by a current of cold water passing through a coil of pipe within the chamber. The principle of the calorimeter is the same as described in previous publications[a] of this Office. A very detailed description of the construction and manipulation of it has recently been published.[b] A brief explanation of the arrangements for preventing the passage of heat through the walls of the chamber and for removing and measuring it will therefore suffice here.

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[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 63, 69, 109, and 136.

[b] Carnegie Inst. Washington Pub. No. 42, p. 106.

GENERAL CONSTRUCTION.

The principle of the construction of the calorimeter as a whole is much like that of an ordinary refrigerator, namely, a chamber surrounded by a series of confined air spaces. The walls, ceiling, and floor of the calorimeter chamber (which is of course the respiration chamber) are copper. On all sides of the chamber the copper is attached to a wooden framework, to the outside of which is fastened a shell of zinc concentric with that of copper, a dead-air space, about 3 inches across, separating the two metal shells. About 3 inches outside of the zinc is a concentric shell of wood, and an equal distance from this is the outer wooden structure. (See frontispiece.) For convenience in access to the exterior of the metal walls, the wooden shells are made in removable panels, and the chamber is mounted on casters, so that it may be rolled out of the wooden casing.

The space between the zinc and the inner wooden shell is the "inner air space," and that between the two wooden shells is the "outer air space," both of which are thus designated hereafter. The wooden casing surrounding the chamber on all sides, and especially the air spaces with the devices for heating and cooling them, mentioned below, afford means for controlling the temperature of the zinc wall and protecting it against fluctuations in temperature of the air surrounding the outer wooden casing.

HEATING AND COOLING THE AIR SPACES.

Gain or loss of heat through the metal walls of the chamber is prevented by keeping the zinc wall at the same temperature as the copper, in which case there will be no exchange of heat between them. For this purpose provision is made for heating or cooling the inner air space, and thus heating or cooling the zinc. The heating is accomplished by passing a current of electricity through a German silver resistance wire installed in the space, the amount of heat being controlled by a rheostat on the observer's table. For cooling, a current of water is passed through a small brass pipe in the same space.

Similar provision is made for heating and cooling the outer air space to aid in protection against changes in temperature of the air in the laboratory. This is especially desirable because, from lack of facilities for heating and cooling the laboratory uniformly, the temperature of the air immediately surrounding the outer wooden wall varies widely at different parts. For example, there may be a difference of 10° between the temperature at the floor and that at the ceiling, due to the fact that the laboratory is a basement room and is heated by steam pipes near the ceiling; and without some such precaution as that described above there might be heat flowing in at the top of the calorimeter chamber and out at the bottom.

THERMOELECTRIC ELEMENTS IN THE METAL WALLS.

In order to know whether to heat or cool the zinc wall, it is necessary to know whether it is colder or warmer than the copper. For this purpose the device introduced by Prof. E. B. Rosa[a] is employed. Thermoelectric elements of iron and German silver wire are installed between the two metal walls in such a way that one end of each element is in thermal contact with the copper and the other end with the zinc wall, and are connected with a delicate galvanometer on the observer's table. The difference between the temperature of the copper wall at one end of the elements and that of the zinc wall at the other end is indicated by the deflections on the galvanometer, one direction showing that the zinc is cooler and the other that it is warmer than the copper, and accordingly whether to heat or cool.

The temperature of the copper wall depends on the rate at which heat is being produced within the chamber and that at which it is being carried out as explained later. An effort is made to have the latter exactly parallel with the former, so as to maintain practically constant temperature within the chamber, but in spite of this regulation, local temperature differences occur in different parts of the walls. For this reason the thermoelectric elements, a large number of which are distributed throughout the walls, ceiling, and floor of the chamber, are connected with each other and with the galvanometer in such a way that it is possible to determine temperature differences between the copper and zinc walls, not only as a whole, but also in four sections, corresponding to the top of the chamber, the upper section, which comprises a little less than half of all four sides, the lower section, comprising the remainder of the four sides, and the floor. Moreover, the heating and cooling circuits are arranged to correspond with these sections, so that one section may be heated or cooled without affecting the others. The observer may therefore note the galvanometer deflections for the different sections, and heat or cool accordingly. It is possible, for example, that the top section may need cooling and the bottom need heating at the same time. An observer with a little skill may keep all the corresponding sections of the zinc and copper walls adiabatic. As a matter of fact, instead of attempting to keep the deflections constantly at zero, they are kept within very small limits and the plus and minus deflections are made to equal each other during a given period. In this way, the small quantity of heat that may pass in one direction is exactly counterbalanced by the quantity passing in the other direction, and there is no actual gain or loss through the walls.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 63, p. 17.

The outer air space is likewise divided into four sections, corresponding to those of the inner space, and each of these sections has its thermoelectric elements and its heating and cooling circuits; and these sections are heated or cooled as needed to keep their temperature in agreement with that of the corresponding sections of the inner space, thus protecting the inner space against fluctuations in temperature of the air of the laboratory.

REGULATION OF THE TEMPERATURE OF THE AIR CURRENT.

In order that the chamber will neither gain or lose heat by changes in temperature of the air current, the temperature of the ingoing air is kept the same as that of the air leaving the chamber. A system of thermal junctions is installed, with one end in the ingoing and the other end in the outgoing air, and provision is made for heating or cooling the ingoing air as indicated by the galvanometer deflections.

REMOVAL OF HEAT FROM THE CHAMBER.

A portion of the heat generated within the chamber is carried out as latent heat of water vapor in the air current. The major portion, however, is removed by a current of cold water which passes through a pipe extending around the chamber near the ceiling and absorbs the heat. To increase the heat-absorbing area, a large number of copper disks are soldered along the pipe.

It has been stated that effort is made to extract the heat just as fast as it is produced, and thus maintain a comparatively constant temperature in the chamber. To this end it is necessary that the rate of absorption may be accurately controlled. This is accomplished in three ways: First, by increasing or diminishing the rate of flow of water through the pipe; second, by raising or lowering the temperature of the water entering the heat absorber; and third, for the finer regulation, exposure of the absorbing area to the heat may be increased or decreased by raising or lowering the metal shields which partially surround the pipe and disks. As the shields are raised they become filled with cold air and act as insulators; when they are lowered a greater absorption area is exposed.

The water pipes and disks and the shields are plainly seen in Plate I, figures 1 and 2, page 40.

MEASUREMENT OF TEMPERATURE OF THE CALORIMETER CHAMBER.

Since the temperature of the calorimeter depends upon the production of heat by the subject, and this varies with the muscular activity, larger or smaller fluctuations in temperature are constantly occurring, especially when there is marked and sudden change in the muscular activity of the subject, as, for example, in going to bed or getting up, or beginning or ending muscular work. If the heat is to be removed in accordance with the rate at which it is produced, so as to maintain approximately a constant temperature, these fluctuations must be detected. Some means for determining the temperature of the chamber is therefore necessary, for which purpose electrical resistance thermometers are used. One series of coils of copper wire having a total resistance of about 20 ohms is distributed in different parts of the chamber so as to determine, as previously explained, the average temperature of the air of the chamber. These coils, though suspended from the walls, are insulated from them and exposed to the air, so as to acquire the temperature of the latter rather than of the former.

Another series of coils of approximately the same resistance is used to determine the temperature of the walls themselves. Each of the coils in this series is inclosed in a small metal box that is attached to the wall, and is in direct thermal contact with the metal. Some of the coils of both series may be seen in Plate I, figures 1 and 2, page 40.

Both series of coils are connected electrically with a special form of Wheatstone bridge and with the galvanometer previously mentioned, and by this means changes in temperature of the air or of the copper wall can be determined to the hundredth of a degree. The variations are always very small, generally amounting to not over a few hundredths of a degree, since the rate of abstraction of heat may be regulated so closely in accordance with that at which it is produced.

If the temperature of the calorimeter is lower at the end than at the beginning of a period it has lost heat; and if it is higher at the end it has gained heat. The amount of heat thus gained or lost is ascertained from the differences in temperature and the hydrothermal equivalent of the calorimeter, which is known to be not far from 60, i. e., 60 calories will raise its temperature 1°.

DETERMINATION OF THE QUANTITY OF HEAT EVOLVED.

The heat removed from the chamber as latent heat of water vapor in the air current is computed from the weight of water absorbed from the air and the factor for latent heat of vaporization. According to the best available data, it requires 0.592 calorie to vaporize 1 gram of water. This factor is used in these computations.

The amount of heat removed from the chamber by the cold water passing through the heat absorbers is computed from the amount of water that passes through the pipe and its rise in temperature during its passage. The quantity of water passing through the absorber is determined by weighing on a special device. The rise in temperature is determined by observation of carefully calibrated mercury thermometers whose bulbs are immersed, one in the ingoing and the other in the outgoing water. These are read every two to four minutes, acording to the rate at which the temperature is changing. Corrections in readings are made for the effect of pressure of water on the bulb of the thermometer. In calculating the quantity of heat removed from the chamber by the water current, the specific heat of water at different temperatures is taken into account. The specific heat of water at 20° C. is taken as unity, and the results are all expressed as calories at 20°.

The sum of the two quantites of heat determined as just described comprises practically that evolved within the chamber, though allowance is made for certain small quantities involved in the change of temperature of the calorimeter mentioned above, and in the pasage of objects into or out of the chamber through the food aperture at a temperature different from that of the chamber.

POSSIBILITIES OF ERROR IN THE MEASUREMENT OF HEAT.

It seems desirable to consider the significance of some possible sources of error in the heat measurement.

PASSAGE OF HEAT THROUGH THE WINDOW OR THE FOOD APERTURE.

By controlling the temperature of the inner and outer air spaces as above described, the greater part of the walls of the chamber is protected against interchange of heat. Two parts of the walls, however, the window and the food aperture, are not thus protected.

The opening in the wall that serves as a window is sealed with a pane of glass, which is in the plane of the zinc wall. Outside of this are two other panes, one in the plane of the inner and the other in the plane of the outer wooden wall. The three plates of glass and the framework in which they are inclosed provide two dead-air spaces which serve to some extent as heat insulators. However, with a constant temperature within the chamber and a variable temperature in the laboratory without, there would be opportunity for passage of heat through the window, and in some of the earlier experiments there was a serious error from this source. The present custom, therefore, is to hang a thermometer immediately outside of the outer pane of glass and to regulate the heat of the laboratory so as to keep the temperature as indicated by this thermometer, so far as possible, the same as that of the chamber. This has been found to afford protection against the passage of any appreciable quantity of heat through the window.

The food aperture is closed by a glass door on each end. One part of the aperture tube is surrounded by the air of the inner air space, another part by that of the outer air space, and those parts of the tube are heated or cooled according as the spaces are heated or cooled, which to a limited extent may help control the temperature of the air within the aperture. Furthermore, since the aperture is at the same level as the widow, and the temperature gradient of the air of the laboratory is from the floor to the ceiling, the control of the temperature of the air of the laboratory mentioned above, to prevent the passage of heat through the window, also affects passage of heat through the aperture.

TEMPERATURE OF THE WATER OF THE HEAT ABSORBER.

Whenever the bodily activity of the subject changes markedly from period to period, the temperature of the water passing through the heat absorbers is changed accordingly, colder water being used during the period of increased muscular exercise to increase the rate of absorption of heat. It frequently happens, then, that there may be warm water in the absorber at the beginning of the period and cold water at the end. Although the quantity of water in the absorber is known to be about 400 cubic centimeters, the distribution of the temperature of the water is not known, nor is that of the large mass of metal of the heat absorbers. There may therefore be an appreciable error in the heat measurements for periods because the amount of heat involved in the changes in temperature of the absorber and water is not known. This error, however, affects only the distribution of heat throughout the short periods of the day, since the average temperature of the water, and probably of the heat absorber, is practically the same each morning at 7 o'clock—i. e., at the end of the experimental day—the measurement of the total quantity of heat for the twenty-four hours is unaffected. Furthermore, the greatest variations in the temperature of water in the heat absorber occur in work experiments—when the heat produced is large—consequently the error due to a neglect of variations is relatively much less than would be the case in rest experiments. If, however, the work period is followed immediately by one of unusual muscular inactivity—such as, for example, when the subject goes to bed—then the heat measurement for the period of sleep would be less than that actually produced, since a considerable portion of it would be required to warm the absorbing system to the temperature which it would have at the end of a rest period. Thus far experimental evidence has not accumulated sufficiently to justify making any definite correction for these possible sources of error in the measurement of heat by short periods.

THE PRACTICABILITY OF THE RESPIRATION CALORIMETER.

The true tests of the practicability of an apparatus such as that used in these investigations are first, that a man can live in it in comparative comfort for several days, and under the conditions of the experiment maintain his normal bodily functions unimpaired; and second, that when known quantities of carbon dioxid, water vapor, oxygen, and heat are introduced, they can be accurately measured by the apparatus.

APPOINTMENTS OF THE RESPIRATION CHAMBER.

The respiration chamber is 7 feet 6 inches long, 4 feet wide, and 6 feet 6 inches high, the dimensions being such as to allow a man to stand or lie down at full length, or even to move about to a limited extent. In one end is an opening through which the subject enters or leaves the chamber at the beginning or end of an experiment. During the experiment this is closed by glass, tightly sealed in place, and serves as a window, admitting ample light for reading and writing. In the opposite end of the chamber is a smaller opening, known as the food aperture, through which receptacles for food, drink, excreta, and other articles may be passed in the course of an experiment. Within the chamber are a chair, a table, and a bed, all of which may be folded and put aside when not in use. For experiments in which muscular work is performed, a device by means of which the amount of work done may be measured is provided. There is a telephone for communication with persons on the outside. The arrangement of the furniture, bed, shelving, etc., in the space available, so as to make the subject comfortable during an experiment which may continue for two weeks, has been adopted as a result of a number of years' experience. The arrangement of different articles in the apparatus is shown in Plate I, figures 1 and 2.

Plate I, figure 1, is a view from the window looking toward the rear of the chamber. In the center of the rear wall is the food aperture, with the inner door open. Above the food aperture are shelves on which may be seen a book, a urine jar, and a feces can. Between these two shelves is one of the electric resistance thermometers used for measuring the temperature of the air; another thermometer of the same series is seen on the wall at the left, back of the chair. Directly above this coil is a small box attached to the wall, which contains a resistance coil of the series used for measuring the temperature of the wall; a second box, with another coil of this latter series, is shown farther up on the wall, near the edge of the picture. The wires from these coils lead to the plug switch seen above the center of the wall at the left in this view. Connections from this switch are also made with the telephone seen hanging from a shelf near the edge of the picture, and with the rectal thermometer, lying on the chair, that is used for electric measurements of body temperature.

The bed, without mattress or covering, is seen folded against the wall at the right, and just above it is the pipe by which air leaves the respiration chamber. Near the ceiling are the heat absorbers, showing the double line of pipe with disks to increase the area and the metal shields that may be raised or lowered to regulate the rate of absorption. Above the heat absorber is one of the equal beams formerly used for weighing the absorbing system. Suspended from the ends of the shields are two metal boxes which catch the water that condenses on the heat absorbers. The irregular light spots seen on the floor and less distinctly on the walls and ceiling show where the thermal junctions are soldered to the copper.

Plate I, figure 2, is a view from the rear of the chamber toward the front. The large opening in the front wall is the window with a dark curtain hanging in it. Just in front of this is a broad, removable shelf, which serves as a table, on which stand some dishes and a bottle of drinking water. Another shelf is seen at the right, above the chair. At the left of the window are two small pipes, one for the incoming and the other for the outgoing water of the heat absorber. The larger pipe to the left of this is the air pipe, the end extending downward carrying air into the chamber.

Every effort is made to keep the subject comfortable and to have the conditions under which the various factors of income and outgo are determined as nearly normal as possible. Up to the time of the last experiment reported in this bulletin, namely, April 6, 1904, 17 men had lived in the chamber for periods varying from three hours to thirteen days, and in no case was there complaint of discomfort.

TESTS OF ACCURACY.

Two methods of testing the accuracy of the apparatus have been employed, one producing heat electrically and the other by burning alcohol in the apparatus. The principles of these tests are here explained, and the results obtained by each method are given.

CHECK TESTS WITH ELECTRICITY.

By this method the accuracy of only the heat measurements is tested. Heat is generated by passing a current of electricity through a resistance coil within the chamber. From the records of the strength of the current, the fall of potential, and the time, the quantity of heat generated is accurately calculated. The temperature of the chamber is kept constant, and the heat evolved is removed from the chamber by the water passing through the heat absorbers, and

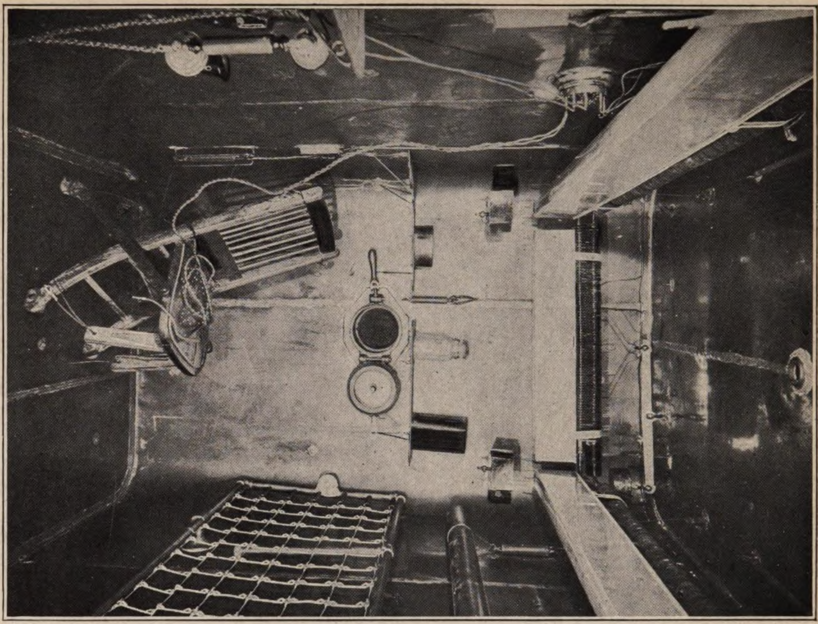

FIG. 1.—INTERIOR OF RESPIRATION CHAMBER. VIEW TAKEN FROM THE WINDOW.

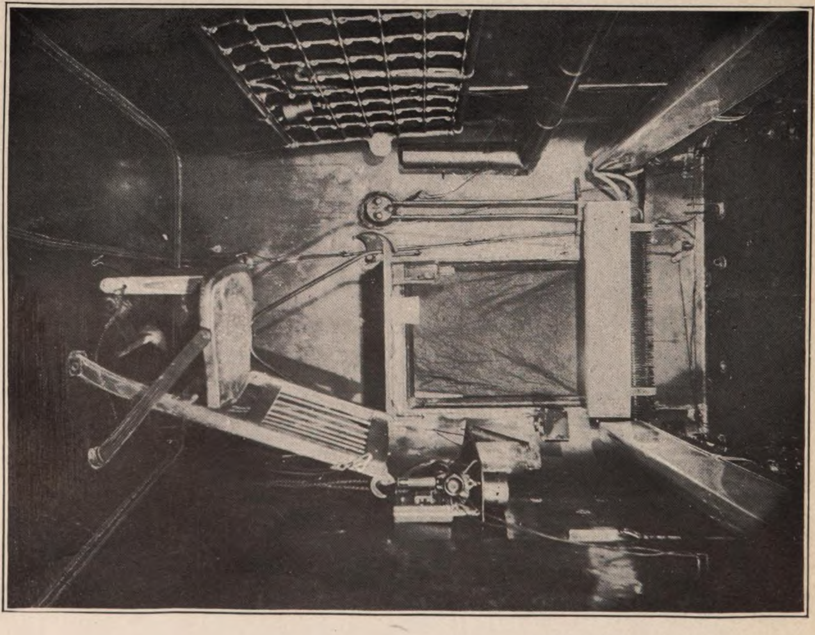

FIG. 2.—INTERIOR OF RESPIRATION CHAMBER. VIEW TAKEN FROM REAR OF THE CHAMBER.

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measured. A comparison of the quantity of heat measured and that generated in two such tests is shown in Table 1.

TABLE 1.—*Results of electrical check experiments with the respiration calorimeter.*

Date.	Duration.	(*a*) Heat generated.	(*b*) Heat measured.	Proportion of heat measured to heat generated, *b*÷*a*.
1904.	*Hrs. Min.*	*Calories.*	*Calories.*	*Per cent.*
October 8	5 31	469.5	468.1	99.70
November 22	8 58	723.7	721.7	99.72
Total	14 29	1,193.2	1,189.8	99.72

The results show very close agreement between the quantity of heat generated and that measured by the calorimeter.

CHECK TESTS WITH ALCOHOL.

A much more satisfactory test of the apparatus is made by burning ethyl alcohol within the chamber. In the combustion of the alcohol oxygen is consumed, and carbon dioxid, water, and heat are produced, and the quantities of each involved in the combustion of a known quantity of alcohol may be very accurately computed. The products of the combustion are removed from the chamber and measured, as is also the quantity of oxygen consumed, exactly as in experiments with men, and these are compared with the computed theoretical quantities. By this method, therefore, both the respiration apparatus and the calorimeter are tested.

The complete oxidation of ethyl hydroxid is represented by the equation $C_2H_6O+3O_2=2CO_2+3H_2O$. The molecular weight[a] of ethyl hydroxid is 46.048, that of carbon dioxid is 44.001, and that of water is 18.015. Since the ratio of ethyl hydroxid consumed to carbon dioxid produced in the equation is $C_2H_6O:2CO_2$, or 46.048 : 88.002, 1 gram of ethyl hydroxid when completely oxidized yields 1.9111 grams of carbon dioxid. In the case of water the ratio is $C_2H_6O:3H_2O$, or 46.048 : 54.045, showing that 1.1737 grams of water is produced. Computed in the same way, 2.0848 grams of oxygen is consumed; but the same figure is obtained by subtracting 1 gram, the weight of ethyl hydroxid burned, from 3.0848 grams, the sum of the weights of water and carbon dioxid produced.

As a result of a considerable number of determinations by use of the bomb calorimeter[b] the heat of combustion of ethyl hydroxid has been found to be, at constant pressure, 7.095 calories per gram.

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[a] The atomic weights used in the computations are H=1.0076; C=12.001; O=16.

[b] Jour. Amer. Chem. Soc., 25 (1903), p. 698.

In practice it has been found unnecessary to use absolute alcohol for the check tests; indeed it is difficult to use it, although, according to the recent researches of Winkler,[a] the hygroscopic nature of alcohol has apparently been overestimated. A number of experiments were made at first with purest absolute alcohol, obtained through the kindness of Dr. E. R. Squibb, of Brooklyn. Some other experiments were made with this absolute alcohol diluted with water. It was found, however, that the better grades of commercial alcohol could be used just as satisfactorily, since the impurities present in them are so small in amount as to have no appreciable influence upon the results. Accordingly high-grade commercial alcohol containing not far from 90 per cent of ethyl hydroxid has been used for a number of years.

To compute the theoretical quantities of carbon dioxid, water, oxygen, and heat involved in the combustion of the commercial alcohol, the percentage of pure ethyl hydroxid present must first be ascertained. For this purpose the specific gravity of the alcohol is determined by use of a form of pyknometer described by Squibb,[b] by means of which results to the fifth or sixth decimal place may be obtained. When the specific gravity is known, the percentage of ethyl hydroxid present in the commercial alcohol may be ascertained from any one of a number of excellent alcoholometric tables. The factors given above for pure ethyl hydroxid, multiplied by the percentage thus obtained, give the corresponding factors for the commercial alcohol.

For example, the commercial alcohol used in one series of experiments contained 91.17 per cent ethyl hydroxid. The oxidation of 1 gram of this alcohol would give $(0.9117 \times 1.9111 =)$ 1.7423 grams of carbon dioxid. Since each gram of the commercial alcohol contains $(1.0000 - 0.9117 =)$ 0.0883 gram of water, present as such, this much would be produced by evaporation. The quantity of water formed by the combustion of the ethyl hydroxid present would be $(0.9117 \times 1.1737 =)$ 1.0701 grams and the sum of these two quantities, 1.1584 grams, would be the total water produced by combustion and evaporation of 1 gram of the commercial alcohol. The sum of the quantities of water and carbon dioxid thus produced, 2.9007 grams, minus the 1 gram of alcohol used, gives 1.9007 grams as the quantity of oxygen required for the combustion.

Since the heat of combustion of ethyl hydroxid is 7.095 calories per gram, that of the commercial alcohol containing 91.17 per cent ethyl hydroxid would be $(0.9117 \times 7.095 =)$ 6.469 calories per gram. This amount, however, is somewhat larger than that which would be actually measured as sensible heat by the calorimeter, because a portion of the heat from the burning of the alcohol would be latent in the water vapor produced and would leave the chamber in the water of the air current. The purpose of the test is to determine the accuracy of the actual measurement of sensible heat removed by the water current in the heat absorbers; consequently the amount of latent heat of water vapor from 1 gram of the alcohol is deducted from the total heat of combustion of 1 gram. It has been shown above that there would be 1.1584 grams of water produced, and since it requires 0.592 calorie to evaporate 1 gram of water, there would be (1.1584 × 0.952 =) 0.686 calorie of heat latent in the water vapor from the combustion of 1 gram of the commercial alcohol. Each gram of the alcohol containing 91.17 per cent ethyl hydroxid would therefore produce on combustion (6.469 − 0.686 =) 5.783 calories that should be measured as sensible heat by the calorimeter.

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[a] Ber. Deut. Chem. Gesell., 38 (1905), p. 3612.

[b] Jour. Amer. Chem. Soc., 19 (1897), p. 111.

The form of lamp used for combustion has been described elsewhere.[a] Careful tests have shown that the oxidation of the alcohol is complete. The alcohol is supplied to the lamp from a reservoir outside the chamber, and the quantity burned is determined by weighing to within 0.1 gram. From this quantity, and the factors obtained as described above, the theoretical quantities of oxygen consumed and of carbon dioxid, water, and heat produced are computed.

This method of checking the accuracy of the respiration calorimeter may be likened to that followed by the organic chemist in verifying the method of elementary organic analysis by combustion of pure cane sugar. In the latter case, however, only two factors (carbon and hydrogen) must agree with the theoretical, whereas, with the respiration calorimeter, there are four factors to be verified. Frequently one or two of these four factors may show considerable discrepancy, while the others are perfectly satisfactory. In general the determinations of carbon dioxid are extremely satisfactory, since there is no opportunity for gain or loss of it, any inaccuracies being usually traceable to errors in residual analysis. In the determination of water, on the other hand, the same difficulties as are experienced by the organic chemist are met with here, the results being frequently somewhat too high, as previously explained (see p. 28). The total amount of water evolved by the combustion of ethyl alcohol, though sufficient to be accurately weighed and to form when properly determined a true test of the apparatus, is relatively small, and the rate of evolution is somewhat slow, so that with the regular rate of ventilation, the quantity of water vapor in the air of the chamber is much below that in ordinary air. With such exceeding dryness, there is evaporation of water from any object in the chamber upon which water has previously been condensed in either visible or invisible quantity, and this water is of course determined along with that actually resulting from the combustion of the alcohol. Since some of the heat that would be otherwise measured as sensible heat is rendered latent in the vaporization of this excessive moisture, it frequently happens that when the percentage of water is abnormal the heat measurement does not accord with the theoretical.

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[a] Carnegie Inst. Washington Pub. 42, p. 99.

In order to show the accuracy of the apparatus in the measurement of the different factors mentioned above, Table 2 gives the results of a typical experiment, which was made December 16–17, 1903, and the summary of the results of all the experiments made between October 20, 1903, and April 29, 1904.

Table 2.—*Results of a typical alcohol check experiment, and summary of all alcohol check tests from October 20, 1903, to April 29, 1904.*

Date.	Duration.	Alcohol burned.	Carbon dioxid.			Water.		
			Found.	Required.	Per cent theory.	Found.	Required.	Per cent theory.
	Hrs. min.	*Grams.*	*Grams.*	*Grams.*		*Grams.*	*Grams.*	
Dec. 16–17, 1903	2 30	50.22	86.02	87.30	98.54	58.47	58.16	100.53
	5 15	101.76	174.27	175.84	99.11	115.73	117.15	98.79
	11 25	212.59	369.63	369.53	100.03	248.24	246.20	100.83
	2 05	40.14	70.96	69.77	101.70	46 52	46.49	100.07
Total	21 15	404.71	700.88	702.44	99.78	468.96	468.00	100.21
Total, all experiments	188 13	4,072.12	7,046.45	7,065.62	99.73	4,783.76	4,713.71	101.49

Date.	Duration.	Alcohol burned.	Oxygen.			Heat.		
			Found.	Required.	Per cent theory.	Found.	Required.	Per cent theory.
	Hrs. min.	*Grams.*	*Grams.*	*Grams.*		*Calories.*	*Calories.*	
Dec. 16–17, 1903	2 30	50,22	96.48	95.23	101.31	295.10	288.98	102.11
	5 15	101.76	183.02	191.83	95.41	582.18	582.10	100.00
	11 25	212.59	405.37	403.14	100.55	1,223.20	1,223.29	100.00
	2 05	40.14	78.27	76.12	102.83	233.13	230.98	100.92
Total	21 15	404.71	763.14	766.32	99.59	2,333.61	2,325.35	100.36
Total, all experiments	188 13	4,072.12	7,581.87	7,709.12	98.35	[a]22,374.95	[a]22,582.50	[a]99.08

[a] Excluding one period of 6 hours and 35 minutes.

In all the experiments here summarized over 4 kilograms of alcohol were burned during a total of 188 hours and 13 minutes. In these experiments the percentage of carbon dioxid measured agreed practically with the theoretical quantity, whereas the percentage of water was slightly too high and those of oxygen and heat slightly too low. These figures conform to the statements made above, that in general the error in the carbon dioxid determination is least, and the water is frequently too high, and since the vaporization of an excess of water results in a diminished quantity of sensible heat, the heat measurement may be affected whenever the water determination is inaccurate.

From the results of the experiment of December 16–17, 1903, shown in detail, it will be seen that the determinations by the respiration calorimeter are on the whole in satisfactory agreement with the theoretical quantities. This is especially the case in the longest of the four periods of this experiment. Subsequent developments in the method of conducting these experiments have given results even more satisfactory than the average for all four periods of this experiment. When it is considered that such results represent an accuracy fully as great as that ordinarily obtained by the organic chemist, if not greater, they afford very satisfactory proof of the precision of the apparatus in the determinations made with it.

ACCESSORY DETERMINATIONS.

In addition to the accurate measure of the heat elimination, the carbon dioxid and water output and oxygen consumption, afforded by the respiration calorimeter, for the proper interpretation of the metabolic transformations in the body, data regarding the chemical composition and potential energy or heat of combustion of the food, drink, feces, and urine are necessary. This knowledge is obtained by means of apparatus and methods common to investigations in physiological chemistry, though considerable attention has been given in this laboratory to the development of methods especially fitted for the particular kinds of foods used in these experiments, and for feces and urine.

METHODS OF SAMPLING.

With highly purified and crystallized organic preparations, an accurate sample can be easily obtained. In physiological experimenting involving large quantities of bulky materials of complex physical and chemical nature and containing a large percentage of water, it is extremely difficult to obtain a sample of the given material which, when prepared for analysis, will be so representative of the whole that the small quantity (0.2 or 0.3 gram) used for each determination will give with sufficient accuracy the proportions of the different elements in the total bulk. Futhermore, because of the possibility of variations in moisture content, it is necessary to use every precaution to insure constant hygroscopic conditions of the different samples.

In selecting the food materials for an experiment, preference is given so far as possible to those which can be prepared in bulk preliminary to sampling. A considerable quantity of each is thoroughly mixed so as to have a uniform or homogeneous character, and it is then subdivided and the different portions are carefully preserved so as to retain their condition at the time of mixing. The sample is taken from the thoroughly mixed material.

DRYING THE SAMPLE.

Wherever possible, the fresh material—i. e., without drying, is used for analysis. Such materials as prepared cereals, crackers, sugar, etc., can be ground for analysis in this condition. With other materials, for example bread, the samples must be dried before they can be ground. Samples of liquids, as milk, cream, and urine, must be dried for some determinations. The total quantity of feces for an experiment is dried and ground and thoroughly mixed. The drying of all these materials is done so far as possible under conditions that will preclude disintegration due to heat, or oxidation, or bacterial action, usually in a large vacuum desiccator at room temperature. The proneness of feces to bacterial decomposition and loss by volatilization makes it especially difficult to prepare them for analysis. In former years, it was the custom to dry them in a water oven, and in some of the experiments here reported this method was followed. More recently, the method mentioned above was adopted. Even under these conditions, there is possibly a slight loss of nitrogen in drying, which should of course be taken into consideration in experiments in which the intake and output of nitrogen is unusually small.

METHODS OF ANALYSIS.

WATER.

Formerly water determinations were made in the usual manner—by heating a known weight of substances at the temperature of boiling water for five hours. In recent years the method described elsewhere by Benedict and Manning,[a] of drying the material in a high vacuum over sulphuric acid has been followed.

NITROGEN.

All determinations of nitrogen are made by the Kjeldahl process, with the use of mercury to favor oxidation. The distillation is carried out in a special form of still described elsewhere.[b]

CARBON AND HYDROGEN.

The determinations of these elements are made by the Liebig process, with such modifications as regards absorbing agents and methods of manipulation as have been suggested by extensive experience in this laboratory.[a]

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[a] Amer. Jour. Physiol., 13 (1905), p. 309.

[b] Jour. Amer. Chem. Soc., 22 (1900), p. 259.

FAT AND ASH.

Fat is determined by the usual process of extracting the previously dried material with anhydrous ether. The mineral matter or ash is obtained by incinerating the given quantity of the material, leaching out the salts, and after ignition of the residue adding the extracted liquors, which are then evaporated at moderately low temperatures.

MISCELLANEOUS DETERMINATIONS.

In certain experiments other data which throw light on the general process of metabolism are obtained. These have to do in large measure with materials in the urine, and involve determinations of creatinin, phosphorus, sulphur, chlorin, etc., all of which are carried out according to the commonly accepted methods. Determinations of sulphur, phosphorus, and chlorin in the food ingested may likewise be made, but the pressure of experimental work thus far has prevented taking account of all these factors.

HEAT OF COMBUSTION.

Data regarding the potential energy of the food and of the unoxidized material in feces and urine are necessary for a comparison of the energy of income with that of outgo. The potential energy of these materials is determined by burning samples in the bomb calorimeter described elsewhere by Atwater and Snell.[b]

In brief, this apparatus consists of a platinum-lined steel shell and cover, the volume capacity of the shell being about 1 pint. The substance to be burned is placed in a metal capsule suspended from the cover. When the cover is securely fastened in place, the shell is filled with oxygen at a pressure of 300 pounds. The bomb is then immersed in water, and the substance ignited electrically. With the excess of oxygen present the combustion is rapid and complete. The heat generated is imparted by the metal of the bomb to the water in which it is immersed. From the weight of the water and its rise in temperature due to the combustion the heat generated is determined.

Two checks on the accuracy of the results obtained by the use of the bomb calorimeter are possible. In the first place, there are several substances, such as cane sugar, benzoic acid, naphthalene, etc., whose specific heat of combustion per gram has been determined in a number of ways, and by a number of investigators with different forms of calorimeter, and may therefore be assumed to be known absolutely. Such substances are burned in the bomb calorimeter, and the results obtained are compared with their true heat of combustion per gram. Another check on the apparatus was pointed out by Atwater and Snell,[a] who showed that when alcohol was burned in the respiration calorimeter in the manner described on preceding pages the heat of combustion thus measured agreed exactly with that as determined by the bomb calorimeter.

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[a] Benedict, Elementary Organic Analysis. Easton, Pa., (1900).

[b] Jour. Amer. Chem. Soc., 25 (1903), p. 659.

PREPARATION OF THE SAMPLE.

The material to be burned in the bomb calorimeter must be freed from excessive moisture, though it need not be absolutely water free. The same precautions against incipient decomposition by heat, mentioned on page 46, must here also be observed. Frequently special methods of preparation are employed, which are so devised that the materials can be weighed in the fresh state whenever possible, thus eliminating error due to partial drying and the consequent sampling. Thus fresh milk and cream are weighed in the capsules in which they are to be burned, and are evaporated therein until dry enough for the combustion. The evaporation may take place in the water oven, but it is more satisfactorily accomplished in the vacuum desiccator.

It has been found especially difficult to obtain accurate results regarding the heat of combustion of urine, because it is very prone to decomposition. After much experimenting, the details of which are not ready for publication, we have adopted the method of drying 15 cubic centimeters of urine with 50 milligrams of pure salicylic acid in a vacuum. The known heat of combustion of the salicylic acid is deducted from the total heat of combustion. This method is by no means perfect, but it has given the most satisfactory results thus far obtained. Recently Farkas and Korbuly[b] have made a valuable contribution to the investigation of this difficult problem.

APPARATUS FOR MEASURING MUSCULAR WORK.

For investigation of the metabolism of matter and energy by the body in the performance of muscular work, a measure of the amount of work done is essential. A special apparatus on which the work of the powerful leg muscles can be utilized has been devised and successfully used for several years. A detailed discussion of this apparatus will be given in a later publication reporting results of several investigations on muscular work. It may be explained in brief as a sort of stationary bicycle, the rear wheel of which is a disk of copper rotating in the field of an electro-magnet which serves as a brake and thus furnishes resistance. The work done in overcoming the resistance appears as heat, and the amount may be very accurately determined.

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[a] Loc. cit., p. 698.

[b] Arch Physiol. [Pflüger], 104 (1904), p. 564.

SUMMARY OF FACTORS DETERMINED IN EXPERIMENTS WITH THE RESPIRATION CALORIMETER.

In summary of the discussion in the preceding pages, it may be said that as a result of the developments and improvements of the apparatus and methods, it is now possible to obtain more complete and more accurate data regarding the metabolism of matter and energy in the body than ever before.

By means of the respiration apparatus, the intake of oxygen from inspired air and the output of carbon and hydrogen in the respiratory products are ascertained. By chemical analysis the intake of nitrogen, carbon, and hydrogen (organic) in the food, and the output of the same elements in the feces and urine, are regularly determined; and, so far as opportunity permits, sulphur, phosphorus, chlorin, and other elements also. Of proximate principles the water, fat, and ash of food and feces, and water and ash of urine may be determined. From the balance of income and outgo of nitrogen, carbon, hydrogen, and oxygen the gains and losses of protein, fat, and carbohydrates by the body are computed in the manner explained in detail on page 71.

The actual output of heat by the body is measured by the respiration calorimeter. The potential energy of intake in food and drink, and that of output in unoxidized materials of feces and urine, are determined as heat of combustion by the bomb calorimeter. From these data the gains or losses of energy by the body are ascertained.

In addition to the above factors, alterations in body weight and body temperature, and the heat equivalent of external muscular work performed, are also measured.

The technique for the determination of all these factors has been gradually improved, and some important data have been obtained in later experiments that have not been previously determined. Since the completion of the experiments reported here the technique has been even more perfected, and not only are the factors mentioned above obtained with more accuracy but the number of factors determined is being continually increased.

DETAILS OF METABOLISM EXPERIMENTS NOS. 56-58, AND 60-67.

The electric and alcohol check tests described on preceding pages proved the accuracy of the determinations of oxygen, carbon dioxid, water vapor, and heat by the modified respiration calorimeter, and two short experiments with men indicated that it was perfectly adapted to experiments of this nature. Accordingly, in the spring of 1903, investigations on the metabolism of matter and energy in the body under different conditions were resumed in continuation of those reported in previous bulletins of this Office,[a] but, as already suggested, with the hope of obtaining more complete and more accurate data than had been possible in the earlier experiments. The following pages contain a detailed account of 11 experiments, Nos. 56–58 and 60–67, numbered consecutively with those previously reported.

OBJECTS OF THE EXPERIMENTS.

It seemed especially fitting that the first of these experiments should be made with J. C. W., the subject of the last series of experiments with the apparatus in its old form, inasmuch as he was available at the time the modified apparatus was in satisfactory condition for the investigation. Furthermore, it seemed desirable to repeat two of the experiments of that series (Nos. 53 and 54[b]), which had special reference to the relative efficiency of fats and carbohydrates as sources of energy in the diet during periods in which the subject was engaged in severe muscular work. These would not only afford comparison of such data as were common to experiments with both forms of apparatus, but also, it was believed, furnish additional data for a clearer interpretation regarding the metabolism of the fats and carbohydrates under the experimental conditions.

In experiment No. 56, which continued three days in April, 1903, the diet was of such nature that a large proportion of the energy was supplied by fat. In experiment No. 57, which continued three days in May, 1903, a large proportion of the energy of the diet was supplied by carbohydrates. In both experiments the subject was engaged in active muscular work on the bicycle ergometer, the amount of work performed being fairly uniform on all six days.

Experiment No. 58 was made in November, 1903, with the subject H. F. The dietetic habits of the subject were different from those which are ordinarily followed, especially regarding attention to chewing and the nature of the food ingested. The specific purpose was to obtain knowledge regarding his energy output and drafts upon body material while consuming a limited diet. During the three days of this experiment the subject was at rest and subsisted on a diet consisting chiefly of carbohydrates and furnishing small quantities of protein and energy.

A three-day fasting experiment, No. 59, was made in December, 1903. The results are reported elsewhere,[c] together with other fasting experiments.

In January, 1904, the subject B. F. D. spent four days in the respiration chamber. The specific purpose of the first three days, which comprised experiment No. 60, was to study the effect of varying quantities of carbon dioxid in the air upon the output of carbon dioxid, water and heat, and the intake of oxygen. During this period the subject was at rest and subsisted on a diet supplying a relatively large proportion of its energy in carbohydrates. On the fourth day, which was experiment No. 61, the subject performed considerable muscular work upon the bicycle ergometer, and the energy of the diet was increased by the addition of a considerable amount of fat.

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[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 69, 109, 136.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, pp. 88–97.

[c] Carnegie Inst. Washington Pub. No. 77.

In April, 1904, the subject A. L. L. spent eleven consecutive days in the respiration chamber, and this period was divided into the series of experiments Nos. 62–67, inclusive. Experiment No. 62 covers the first three days of the period, during which the subject performed work upon the bicycle ergometer, and subsisted on a diet supplying a large proportion of its energy in carbohydrates. Experiment No. 63, which covers the next three days, differed from the first in that the diet was altered so as to contain a preponderance of fat.

In experiment No. 64, which covered the seventh day of the period, the diet was the same as on the first three days, but the amount of muscular work performed was much greater. On the eighth day, which comprised experiment No. 65, the subject subsisted on a much smaller diet and spent most of the time resting and sleeping.

Experiment No. 66 covered the ninth day, and No. 67 the tenth and eleventh days of the period. The purpose in these two experiments was to determine the amount of work incidental to the use of the bicycle ergometer, aside from that actually involved in overcoming the resistance due to the electric brake. During experiment No. 66 the subject prepared himself and the ergometer for riding at the usual times just as in an ordinary work experiment, then dressed and spent the remainder of the time as an ordinary rest experiment. During experiment No. 67 he rode the bicycle ergometer for the usual period of eight hours each day, but no resistance was applied to the disk, the energy expended being merely that required to keep the legs and pedals in motion.

SUBJECTS.

The statistics regarding the age, body weight, normal chest measure, and body surface of the four subjects of these experiments are given in Table 3.

TABLE 3.—*Statistics of subjects of metabolism experiments Nos. 56–58 and 60–67.*

Subject.	Occupation.	Number of experiments.	Duration.	Age.	Body weight without clothing.		Height.		Normal chest measure.		Body surface.[a]	
			Days.	*Yrs.*	*Lbs.*	*Kgms.*	*Ft. in.*	*Meters*	*In.*	*Cm.*	*Sq. ft.*	*Sq. meter.*
J. C. W....	Teacher...	2	6	25	167.9	76.3	5 10	1.78	37.0	94.0	23.90	2.22
H. F......	Author...	1	3	54	157.5	71.6	5 6	1.68	......	......	22.82	2.12
B. F. D....	Student..	2	4	23	147.0	66.8	5 7	1.70	35.8	91.0	21.85	2.03
A. L. L....	.....do....	6	11	23	159.3	72.4	5 5	1.66	39.3	99.8	23.03	2.14

[a] Computed by the formula of Meeh; $S=12.312\times\sqrt[\frac{3}{2}]{W}$, when S is the surface of the skin in square centimeters and W the weight of the body in grams.

The subject J. C. W. was a former student at Wesleyan University, and the subject of experiments Nos. 35 to 55 previously reported.[a] His experience in the calorimeter rendered him especially valuable in the first experiments with the new form of apparatus. The body measurements given above show that he was a man considerably above average height and average weight. His general build was symmetrical and typical of the athlete, with well developed muscles. During his college course he had been a bicycle racer. At the time of these experiments he was apparently in perfect health, and although he had not been specially training upon the bicycle, he had been skating a great deal during the preceding winter, and always made a practice of keeping in the best training form.

The subject H. F. was 54 years of age, and, as is seen from the measurements of height and body weight, was somewhat stout. In fact, with a height of 4 inches less than the first subject, his body weight was but 4.7 kilograms lower. No data as to to his normal chest measure were obtained. He was of rather athletic physique and active disposition, and accustomed to considerable muscular exercise. This subject had been in the respiration chamber six months before for a short preliminary experiment of twenty-four hours, in which, however, the complete determinations of income and outgo were not secured, as the experiment was made before the apparatus was fully developed.

Subjects B. F. D. and A. L. L. were students in Wesleyan University, both of them of muscular build, and rather above the average of the undergraduate in physical development.

COLLECTION OF FECES.

In accordance with our usual custom, feces were separated by the administration of lampblack in gelatin capsules, given with the first meal of the test diet at the beginning of the experiment, and with the first meal after the conclusion of the test diet, generally breakfast. That portion of the feces colored by the lampblack first taken was assumed to pertain to the test diet, while at the end all the feces colored by lampblack were rejected. The time of defecation and the weight of the feces were recorded. The separate defecations during a given experiment were weighed and partially dried, then weighed again and combined, and the total quantity ground and mixed for analysis.

While in the respiration chamber the subjects defecated in copper cans provided with well-fitting covers. The act of defecation unfortunately creates considerable disturbance in the regularity of the heat measurements by short periods, since the hour for defecation is not always the same from day to day. It is found that subjects who are perfectly regular in the time of defecation when on normal diets may experience marked irregularities during a test diet. This may be ascribed either to the peculiar nature of the diet or to the lack of muscular exercise out of doors. In experiments of short duration, one day or less, it is at times possible to obviate this difficulty by giving the subject an enema of warm water just previous to the experiment, thus emptying the lower bowel so that there will be no need to defecate during the period. In long experiments this is of course not feasible, and consequently the error in periodic heat measurements incidental to irregular defecation can not be avoided. In general, however, with subjects who have been upon the diet for several days, reasonable regularity in the time of defecation may be expected.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136.

COLLECTION OF URINE.

The experimental day ends at 7 a. m. The subject, who has been sleeping during the night, is awakened in time to void his urine at that hour. The urine then passed is considered as part of the total for the twenty-four hours ending at that time.

The urine is commonly collected in short periods. In some cases these have been so divided that the distribution of the elimination of nitrogen over the twenty-four hours could be determined. In some of the earlier experiments the collection was made in 6-hour periods, day and night, but some of the subjects, when awakened to urinate at 1 a. m., had difficulty in falling asleep again. In the experiments here reported the urine was collected in periods ending at 1 p. m., 7 p. m., 11 p. m., and 7 a. m. The subjects retire at 11 p. m., and usually, with the diets and amounts of drinking water ordinarily consumed, there is no inclination to pass urine between this hour and 7 a. m.

The urine is collected in ordinary glass jars with glass covers easily clamped upon them. The closure of the cover is made perfectly tight by a rubber gasket, which is carefully inspected each time a jar is used. The jars are thoroughly dried and weighed previous to use, and the increase in weight gives the weight of urine. From the total amount voided in each period an aliquot portion, generally two-thirds, is made part of a composite sample for the day; the remaining portion is used for the determination of the nitrogen elimination by periods. The percentage of nitrogen and heat of combustion per gram are determined from a sample of the composite for the day. Formerly, and indeed in some of the experiments here reported, formalin was added to preserve the urine samples; but recent experience has shown that it is best to make the determinations with the fresh urine as soon as possible after it is taken from the respiration calorimeter.

From aliquot portions of the composites for the several days of an experiment another composite for the total experimental period is prepared and samples of this are dried for determinations of carbon, hydrogen, and heat of combustion.

PERIODIC DETERMINATION OF RESPIRATORY PRODUCTS, OXYGEN, AND HEAT.

The measurements of the consumption of oxygen and the elimination of carbon dioxid and water vapor were made in 3-hour periods in these experiments (except on the first day of experiment No. 56 on which the periods were six hours), and are, therefore, not parallel to the determinations of nitrogen excretion. The measurements of heat are such that the heat removed from the calorimeter by the water current in the heat absorbers may be computed for almost any desired period, but the latent heat of water vapor in the air current can be determined only for periods corresponding to those of the determinations of the water vapor removed from the air.

PRELIMINARY EXPERIMENTAL PERIODS.

For several days just preceding those that are to be spent in the respiration chamber, the subject is placed under conditions as nearly as practicable the same as those to be observed during the experiment, especially as regards muscular activity and diet. The purpose of this preliminary feeding period is principally to bring the body into approximate nitrogen and carbon equilibrium under the experimental conditions. Any changes in the ration, or in the amount of work to be performed that may seem necessary or advisable are made during this period. In former experiments, and also in connection with some of those here reported, the feces corresponding to the food of this preliminary period were separated and the digestibility of the food was ascertained. In later experiments, although the preliminary feeding was continued, the digestibility of the food during this period was not so regularly determined.

On the last day of the preliminary feeding period the subject enters the respiration chamber, generally in the evening, and retires at 11 p. m. This preliminary night period allows the observer outside to bring the condition of the chamber as regards temperature and carbon dioxid and water vapor of the air current to correspond with those during the experiment. At 7 a. m. the subject is aroused and the experiment begins.

The particular reason for beginning and ending the experimental day at 7 a. m. is that the conditions of the body with respect to muscular activity, materials in the alimentary tract, etc., are believed to be more nearly uniform from day to day at the end of a night's rest and after the longest period between meals than at any other period of the day. In all the experience with the respiration calorimeter no other division of time has proved so advantageous as this.

ORDER, DURATION, AND CHARACTER OF EXPERIMENTS HERE REPORTED.

As previously stated, the experiments here reported are numbered consecutively with those published in former bulletins. Their chronological order, duration, and character are shown in the following tabulation, the preliminary digestion experiments and corresponding metabolism experiments being grouped in series.

TABLE 4.—*Duration and character of metabolism experiments Nos. 56–58 and 60–67 and corresponding preliminary periods.*

	Subject.	Duration.	Character of diet.	Muscular activity.
Series 19, Apr. 23–29, 1903:		*Days.*		
Preliminary digestion experiment No. 614.	J. C. W.	4	Fat	Work.
Metabolism experiment No. 56	do	3	do	Do.
Series 20, May 3–9, 1903:				
Preliminary digestion experiment No. 616	do	4	Carbohydrate	Do.
Metabolism experiment No. 57	do	3	do	Do.
Series 21, Nov. 7–12, 1903:				
Preliminary digestion experiment[a]	H. F.	3	do	Rest.
Metabolism experiment No. 58	do	3	do	Do.
Series 22, Jan. 21–30, 1904:				
Preliminary digestion experiment No. 619	B. F. D.	6	do	Do.
Metabolism experiment No. 60	do	3	do	Do.
Metabolism experiment No. 61	do	1	do	Work.
Series 23, Apr. 12–26, 1904:				
Preliminary digestion experiment No. 622	A. L. L.	4	Mixed	Do.
Metabolism experiment No. 62	do	3	Carbohydrate	Do.
Metabolism experiment No. 63	do	3	Fat	Do.
Metabolism experiment No. 64	do	1	do	Severe work.
Metabolism experiment No. 65	do	1	Carbohydrate	Rest.
Metabolism experiment No. 66	do	1	do	Do.
Metabolism experiment No. 67	do	2	do	Light exercise.[b]

[a] No separation of feces was made between the preliminary period and that of the metabolism experiment.

[b] Running the bicycle ergometer without external resistance.

EXPERIMENTAL DATA AND THE CALCULATION OF RESULTS.

The discussion of the experiments and the computations of the metabolism of matter and energy are given on the pages immediately following. The fundamental data of the experiments from which those used in the discussion beyond are derived are given in Tables 106 to 122 of the Appendix. They are given there in detail for the shorter periods into which the experiments were divided, but are summarized in the account that follows here for each day of an experiment and for each experiment as a whole.

The computations involved in the estimation of the metabolism of matter and energy from the data obtained in the experiments are somewhat complicated. The different steps in the calculations are explained in detail in the account of experiment No. 56. Since the same method is followed in all experiments, this explanation need not be repeated in each case.

METABOLISM EXPERIMENT NO. 56.

The first complete metabolism experiment with the new form of respiration calorimeter was No. 56, made in April, 1903. This experiment and No. 57 were essentially repetitions of, respectively, Nos. 54 and 53, two experiments of the last series with the older form of apparatus. The specific object was a continuation of the study of the relative efficiency of food fats and carbohydrates as sources of energy during muscular work. The subject was J. C. W., who had served in the preceding series and in a large number of earlier experiments.

A preliminary digestion experiment of four days' duration began with breakfast April 23. During this period the subject consumed the same diet as was to be given in the metabolism experiment and regulated his muscular activity in accordance with the amount of external muscular exercise which he would perform when in the respiration chamber. He devoted a considerable part of each day to riding a new form of bicycle ergometer that was to be used for the measurement of muscular work, accustoming himself to its use and deciding upon the amount of resistance suitable for the entire eight hours' riding.

At 10 p. m. of April 26, the fourth day of the preliminary period, the subject entered the respiration chamber, and, after adjusting the furniture and fixtures, retired at 11 p. m. Metabolism experiment No. 56 began at 7 the following morning and continued three days, until 7 a. m. April 30.

DAILY PROGRAMME.

Since the transformations of energy in the body are governed so largely by the bodily activity, the latter must be as nearly uniform as possible in experiments in which comparison of the transformations of energy is to be made. For this reason the regulation of the muscular activity of the body is an essential condition of both the rest and the work experiments. Even in the work experiments in which a very large proportion of the total expenditure of energy is concerned in the measured work upon the bicycle ergometer it is desirable to have the remaining activity as nearly uniform as possible on different days. Experience has shown that in order to secure the greatest uniformity in the muscular movements of the subject these should be governed by a prearranged schedule. A copy of such programme is given to the subject inside the chamber and others are supplied to the observers outside, who make sure that it is followed as closely as possible. The daily programme for experiment No. 56 follows:

TABLE 5.—*Daily programme, metabolism experiment No. 56.*

7.00 a. m.	Take pulse and temperature.
7.03 a. m.	Pass urine, weigh self dressed, collect drip, and weigh absorbers.
7.30 a. m.	Breakfast; drink 400 grams water.
8.15 a. m.	Begin work.
10.15 a. m.	Stop work; drink 250 grams water.
10.30 a. m.	Begin work.
12.30 p. m.	Stop work.
12.50 p. m.	Remain quiet
1.00 p. m.	Pass urine, collect drip, and weigh absorbers.
1.25 p. m.	Dinner; drink 400 grams water.
2.00 p. m.	Begin work.
4.00 p. m.	Stop work; drink 250 grams water.
4.15 p. m.	Begin work.
6.15 p. m.	Stop work; change underclothing.
6.20 p. m.	Supper; drink 400 grams water.
6.50 p. m.	Remain quiet.
7.00 p. m.	Pass urine, weigh self dressed, collect drip, and weigh absorbers.
9.00 p. m.	Drink 250 grams water.
10.45 p. m.	Arrange bed.
11.00 p. m.	Pass urine; retire.

At 7 a. m. the subject was called by telephone. In this particular experiment his first duty was to count the pulse and ascertain the body temperature with a clinical thermometer before rising. After these were recorded the subject arose, voided the urine, dressed, and weighed himself.[a] The subject next collected the "drip water" condensed on the heat absorbers in dry, previously weighed bottles. Since a considerable quantity of moisture remained adhering to the surface of the heat-absorbing system the absorbers were weighed.[a]

At 7.30 breakfast was eaten and a definite quantity of water was drunk. After breakfast the subject made preparations for the morning work, such as removing his ordinary clothing, adjusting the seat, handle bars, and the pedals of the bicycle ergometer, making the electrical connections, and reading the counter. At 8.15 he began work and continued, usually without stopping, until 10.15, when he rested for fifteen minutes, during which time he drank more water. At 10.30 he resumed work and continued without interruption for two hours. He then stopped, put on his outer clothing, moved the ergometer to one side, and sat down. At 12.50, ten minutes before the end of the period, he was cautioned to be especially quiet, sitting as still as possible in the chair, since it was desired to secure even temperature conditions inside the chamber just at this time.

The schedule for the next six hours was much the same as that for the morning period. At 1 p. m. the subject again voided urine, collected the drip water, and weighed the absorbers. At 1.25 he ate dinner and drank water. Work began again at 2 p. m. and continued for two hours, at the end of which the subject stopped for fifteen minutes' rest and a drink of water. At 4.15 he resumed work and continued until 6.15, at which time the last work period for the day ended. He then removed his damp underclothes and put on a dry union suit and dressed himself, ate his supper, and drank water. He remained quiet from 6.50 until 7 p. m., then voided urine, weighed himself dressed, collected the drip water, and weighed the absorbers. At 9 p. m. he drank water. At 10.45 he arranged his bed for the night, and at 11 o'clock he voided urine and retired.

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[a] In this experiment and in others up to No. 62 the subject determined the weights of himself, the heat absorbers, etc., in the same way as in earlier experiments—that is, by means of weighing devices inside the respiration chamber. In experiment No. 62 and those following the weights were determined by means of a device for weighing from outside the chamber. (See Carnegie Inst. Washington Pub. No. 42, p. 158.)

The above programme is essentially the same as that of earlier work experiments, being altered slightly for changes in the method of experimenting, the introduction of different pieces of apparatus, and subdivision of the experimental periods.

STATISTICS OF FOOD, FECES, AND URINE.

The diet in this experiment was very simple, consisting of bread, ginger snaps, shredded wheat, butter, milk, and cream, with an infusion of cereal coffee. This was in accordance with the conditions already explained on page 45 regarding the necessity for accurate sampling and analysis. The results of the analyses, including determinations of the heats of combustion per gram, of the different food materials and also of the feces and urine are given in the following table:

TABLE 6.—*Percentage composition and heat of combustion per gram of food materials, feces, and urine in metabolism experiment No. 56.*

Laboratory No.	Kind of material.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion per gram.
		Per ct.	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cals.*
3636	Bread	38.8	8.3	1.5	50.5	0.9	1.46	27.88	4.05	2.749
3637	Ginger snaps	7.5	5.2	9.0	75.9	2.4	.91	42.41	6.14	4.244
3638	Shredded wheat	8.2	9.7	1.7	78.8	1.6	1.70	41.32	5.65	4.021
3639	Butter	8.8	1.3	86.2	......	3.7	.20	64.68	10.51	8.024
3642	Milk[a]	85.8	3.7	4.4	5.3	.8	.60	7.58	1.18	......
3643	Cream	69.2	2.8	23.4	4.0	.6	.45	20.96	3.16	......
3644	Cereal coffee infusion	99.1	.1	......	.8	......	[b].01	[b].47	[b].07	.038
3646	Feces	79.8	4.7	5.1	6.6	3.8	.75	11.18	1.70	1.289
	Urine, first day[c]	95.3	......	......	......	.9	.96	.77	.20	.098
	Urine, second day[c]	95.3	......	......	......	.9	1.59	1.29	.32	.134
	Urine, third day[c]	95.3	......	......	......	.9	1.79	1.46	.37	.144

[a] See explanation on p. 60. [b] Assumed from earlier analysis. [c] See explanation on p. 61.

Of the data given above, the proportions of water, fat, ash, nitrogen, carbon and hydrogen, and the heats of combustion were directly determined. The proportion of protein was calculated in the usual manner from the percentage of nitrogen by an appropriate factor for each kind of food material. The proportion of carbohydrates was determined in each case by difference. The data that are used in the computations of metabolism beyond are those actually determined for water, chemical elements, and energy. The proportions of protein computed by factor, of carbohydrates by difference, etc., are used only in estimating the digestibility of the food.

The total weight of each kind of food per day and the quantities of different compounds and elements and of energy supplied, are shown in Table 7. The corresponding data for the feces and urine are also included in the table.

Table 7.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiment No. 56.*

Laboratory No.	Kind of material.	(a) Total weight.	(b) Water.	Water free substance.								
				(c) Protein.	(d) Fat.	(e) Carbohydrates.	(f) Ash.	(g) Nitrogen.	(h) Carbon.	(i) Hydrogen.	(k) Oxygen by difference.	(l) Heat of combustion.
	Food.											
	Basal ration.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3636	Bread	440	170.7	36.5	6.6	222.2	4.0	6.42	122.67	17.82	118.39	1,210
3639	Butter	45	4.0	.6	38.8	......	1.6	.09	29.11	4.73	5.47	361
3637	Ginger snaps	60	4.5	3.1	5.4	45.6	1.4	.55	25.45	3.68	24.42	255
3638	Shredded wheat	40	3.3	3.9	.7	31.5	.6	.68	16.53	2.26	16.63	161
	Sugar	45	......	......	......	45.0	......	......	18.95	2.92	23.13	178
3644	Cereal coffee	1,200	1,189.2	1.2	......	9.6	......	.12	5.64	.84	4.20	46
	Total basal ration	1,830	1,371.7	45.3	51.5	353.9	7.6	7.86	218.35	32.25	192.24	2,211
	Supplemental ration.											
	First day:											
3642	Milk	1,000	858.0	37.0	44.0	53.0	8.0	6.00	75.80	11.80	40.40	853
3643	Cream	1,020	705.8	28.6	238.7	40.8	6.1	4.59	213.79	32.23	57.49	2,484
	Total ration	3,850	2,935.5	110.9	334.2	447.7	21.7	18.45	507.94	76.28	290.13	5,548
	Second day:											
3642	Milk	1,000	858.0	37.0	44.0	53.0	8.0	6.00	75.80	11.80	40.40	865
3643	Cream	1,070	740.4	30.0	250.4	42.8	6.4	4.82	224.27	33.81	60.30	2,473
	Total ration	3,900	2,970.1	112.3	345.9	449.7	22.0	18.68	518.42	77.86	292.94	5,549
	Third day:											
3642	Milk	1,000	858.0	37.0	44.0	53.0	8.0	6.00	75.80	11.80	40.40	903
3643	Cream	1,130	782.0	31.6	264.4	45.2	6.8	5.09	236.85	35.71	63.55	2,485
	Total ration	3,960	3,011.7	113.9	359.9	452.1	22.4	18.95	531.00	79.76	296.19	5,599
	Excreta.											
3646	Total feces for 3 days	719.1	573.8	33.8	36.7	47.5	27.3	5.39	80.40	12.22	19.99	927
	Average per day	239.7	191.3	11.3	12.2	15.8	9.1	1.80	26.80	4.07	6.66	309
	Urine Apr. 27–28	1,495.6	1,425.8	......	......	......	14.1	14.31	11.57	2.92	26.90	147
	Urine Apr. 28–29	973.0	927.5	......	......	......	9.1	15.49	12.52	3.16	5.23	130
	Urine Apr. 29–30	959.1	914.3	......	......	......	9.0	17.17	13.96	3.52	1.15	138
	Total urine for 3 days	3,427.7	3,267.6	......	......	......	32.2	46.97	38.05	9.60	33.28	415

The diet in this experiment was intended to be as nearly as possible the same as that of experiment No. 55—to furnish about 18 grams of nitrogen and 5,500 calories of energy per day. Not only were the same kinds of food materials used, but also, except for the milk and cream, each was used in exactly the same amount as in the previous experiment. The ration was divided into a basal and a supplemental portion, the basal ration consisting of those materials that could be prepared beforehand in definite quantities, and the supplemental, consisting of the milk and cream, those that had to be prepared each day. The materials in the basal ration had not, of course, exactly the same composition as the similar materials used in experiment No. 55, hence the total amount of nitrogen and energy derived from these substances was slightly different from that in the earlier experiment. It was believed that by proper manipulation of the quantities of milk and cream supplied a definite amount of nitrogen and energy could be maintained in the ration. Unfortunately this was not accomplished as accurately as desired, consequently the amount of energy ranged from 5,548 calories on the first day to 5,599 calories on the third day.

Since this experiment was designed to study the efficiency of fat as a source of energy for muscular work, as large a proportion as practicable of the energy of the diet was supplied by fat. The total quantity of fat in the diet ranged from 334 to 359 grams. Since this was all butter fat, with a heat combustion of approximately 9.3 calories per gram, the quantity of energy from fat ranged from 3,100 to 3,350 calories, or about 60 per cent of the total quantity of energy in the diet.

Both milk and cream were, as already suggested, obtained fresh daily, and the subject used milk and cream from two lots each day, that delivered at the laboratory in the morning being used at dinner and supper of the same day and at breakfast of the next day, so that four lots of milk and cream were used for three days. The quantity of nitrogen and the heat of combustion per gram of both milk and cream were determined as soon as possible after they were delivered at the laboratory. The same quantity of milk was used each day, but the quantity of cream was regulated in accordance with these determinations so as to bring the total amount of nitrogen and of energy in the diet to agree with that decided upon before the experiment began. The total heat of combustion for milk and cream given in the final column of Table 7 is therefore composed of two factors in each case. On the first day of experiment No. 56 the milk consumed consisted of 325 grams of one lot with a heat of combustion of 0.857 calories per gram, and 675 grams of another lot with a heat of combustion of 0.851 calories per gram, making the total quantity of milk 1,000 grams and the total energy 853 calories. On the second day there were 350 grams of the milk with a heat of combustion of 0.851 calories per gram, and 650 grams of a lot with a heat of combustion of 0.873 calories per gram. On the third day there were 350 grams of the milk with a heat of combustion of 0.873 calories per gram, and 650 grams of milk with a heat of combustion of 0.919 calories per gram. For the analysis of the milk a composite sample consisting of aliquot portions of each lot of milk used was prepared. The same is true with respect to the cream used. For this reason no figure for heat of combustion per gram of either milk or cream is given in the final column of Table 6, the other data for these two materials being the analyses of the composite samples. The figures in the last ten columns of Table 7 are derived from those in column *a* regarding the total weight of material, and the data in Table 6 regarding percentage composition and heat of combustion of the food materials, except that the data in column *k* are calculated by difference by subtracting the sum of columns *f*, *g*, *h*, and *i* from the difference between columns *a* and *b*.

In accordance with the usual custom, the total quantity of feces for the three days of the experiment was used as a sample for analysis. From the results of the analysis and the total weight of the material, the quantities of water, compounds, and elements given in Table 7 were computed. One-third of each, or the average quantity per day, is used in the subsequent computations of metabolism of matter and energy for the different days of the experiment.

In the case of the urine, the proportion of nitrogen and the heat of combustion per gram were determined in the material for each day. The proportions of carbon and hydrogen were determined from a composite sample containing aliquot portions of urine for each day and were apportioned among the separate days in accordance with the nitrogen determinations. This was not done in the case of water, however, consequently there is a slight error in the water data for the separate days, but it is insignificant.

ERRORS IN ASSUMING OXYGEN "BY DIFFERENCE."

At present there is no method for determining directly the quantity of oxygen in the solid materials of food and excreta, hence it is computed "by difference," as stated above. This is, of course, inaccurate, since any errors in the determination of the other ingredients affect the value for oxygen. Thanks to the Kjeldahl method, errors attending the determination of nitrogen are now in large measure avoided, and the experimental technique connected with the determination of carbon and organic hydrogen has been so developed as to eliminate in large part the errors usually accompanying these determinations. At the same time, there are still two serious sources of errors, which ultimately affect the oxygen determination, namely, the determination of water in the fresh material, and the determination of mineral matters or ash.

Considerable experimenting has been carried out in this laboratory with a view to determining accurately the water content of foods, feces, and physiological preparations. The difficulties experienced have been much greater than were at first anticipated. By prolonged desiccation over sulphuric acid in a high vacuum, it has been found possible to abstract the moisture from compounds of this nature without affecting the molecular composition of the other chemical compounds, but even with the improved method there are, with many compounds, some difficulties due to their hygroscopic nature that probably result in errors, which must ultimately affect the oxygen determination.

The greatest sources of error, however, are in the determination of ash or mineral constituents. The method for the determination of ash, as at present carried out, while sufficing for the analyses of commercial products, is still too unsatisfactory to remain as a standard for analyses accompanying physiological experimenting. The differences in the amount of carbon dioxid retained by an alkaline ash, especially in urine, the hygroscopic nature of many of the salts formed, the volatility and proneness to decomposition of ammonium compounds, and the loss of sulphur and phosphorus, are all factors which are as yet but too little understood and too unsatisfactorily regulated. So far as the balance of ash is concerned these errors are probably of no great significance, but with the attempt to estimate accurately the amount of oxygen in the food, feces, and urine the errors accompanying the ash determination have a new significance.

Fortunately the amount of oxygen in the dry matter of food, feces, and urine, when compared to the total quantity of oxygen in the intake and output, is relatively small and consequently the percentage error is not large. It is clear, however, that every precaution should be taken to eliminate this error and insure the greatest possible accuracy in the estimation of oxygen by difference.

WATER OF RESPIRATION AND PERSPIRATION.

The data from which is determined the amount of water eliminated by the subject in respiration and perspiration consists of the quantity of water vapor absorbed from the ventilating air current, the amount of moisture residual in the air of the chamber, the amount condensed on the heat absorbers when there is muscular exercise, and the amount absorbed by the underclothes during profuse perspiration. These data, which are given in detail for the different experiments in the Appendix, are summarized here for experiment No. 56.

TABLE 8.—*Daily record of water of respiration and perspiration metabolism experiment No. 56.*

Date.	(*a*) Total amount of vapor in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding day.	(*c*) Change in weight of absorbers, gain (+) or loss (−).	(*d*) Amount in underclothes.*	(*e*) Total amount gained (+) or lost (−) during day, *b*+*c*+*d*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration,* *e*+*f*.
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
April 27–28	63.14	+8.50	+2,343.60	110.1	2,462.20	1,240.07	3,702.27
28–29	63.70	+ .56	+2,667.20	158.9	2,826.66	1,353.12	4,179.78
29–30	60.37	−3.33	+2,458.20	203.9	2,658.77	1,248.37	3,907.14
Total, 3 days	....	+5.73	+7,469.00	472.9	7,947.63	3,841.56	11,789.19

* Including solids of perspiration. See explanation below.

In the above table column *a* shows the total amount of water vapor remaining in the chamber at the end of each day of the experiment, as ascertained from analysis of the residual air (see p. 21). The variations between the amounts at the ends of the succeeding days, which are shown in column *b*, indicate, according to whether they are preceded by a plus or minus sign, an increase or decrease in the amount of residual moisture in the air for the corresponding period. The amount of water condensed on the heat absorbers is recorded in column *c*. In work experiments such as this one, this amount is very large and includes both that actually weighed as moisture condensed on the absorbers themselves and that collected as drip water in the troughs of the shields to the heat absorbers from which it is drawn into bottles and weighed. The figures in column *d*, representing the amount of moisture absorbed by the underclothing worn by the subject during the working periods, are determined from the increase in the weight of the underclothes, which are changed each day about 6 p. m., shortly after the day's work is finished. There is a slight error in these figures, because the material absorbed by the clothing contained some solids. The effect of this error is very small, and no allowance has been made for it in any of the experiments here reported, though of course correction should be made for the amount of solid material in determining the absolute quantity of moisture in the underclothing. The moist clothes were washed in distilled water to extract the solid matter retained by them, and the amount of nitrogen in the wash water was determined, as shown later (Table 12), but the total weight of solids was not ascertained.

The total amount of moisture in the air that leaves the chamber is shown in column *f*. This amount added to that in column *e*, which is the algebraic sum of columns *b*, *c*, and *d*, is given in column *g* as the total water of respiration and perspiration. Corrections should be made, however, for gain or loss of moisture due to changes in the hygroscopic condition of the bed, bedding, furniture, etc. In this experiment and in the five following it, the determination of these changes in moisture content of the various articles within the respiration chamber could not be made, but with the introduction of the new weighing device mentioned on page 194, the change in the weight of these articles was determined with considerable accuracy.

CARBON DIOXID ELIMINATED.

Unlike the determination of water, in which case a very large proportion of the vapor given off from the lungs and skin is condensed on the heat absorbing device and collected therefrom as drip water, the carbon dioxid is wholly (except for a small residual amount) carried out of the chamber by the ventilating air current and removed from the air by the soda lime with which it is brought in contact. The total amount of carbon dioxid eliminated during the day is, therefore, determined by weighing the cylinders of soda lime at the beginning and end of the period and making due allowance for variations in the amount of carbon dioxid residual in the air of the chamber. The data regarding the entire elimination of carbon in experiment No. 56 are summarized in Table 9.

TABLE 9.—*Daily record of carbon dioxid in ventilating air current, metabolism experiment No. 56.*

Date.	Carbon dioxid.					(f)
	(*a*) Total amount in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding day.	(*c*) Total amount absorbed from outcoming air.	(*d*) Amount exhaled by subject, $b+c$.	(*e*) Volume exhaled by subject, $d \times 0.5091$.	Carbon in carbon-dioxid exhaled, $d \times \frac{3}{11}$.
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
April 27-28	40.53	−2.02	1,777.63	1,775.61	903.96	484.25
28-29	38.15	−2.38	1,815.94	1,813.56	923.28	494.60
29-30	35.49	−2.66	1,700.07	1,697.41	864.15	462.91
Total, 3 days	....	−7.06	5,293.64	5,286.58	2,691.39	1,441.76

The quantity of carbon dioxid in the air of the chamber at the end of each experimental day, as shown by analyses of the residual air, is given in column *a*, and the difference between the quantity on one day and that on the preceding day in column *b*. In rest experiments the variations for 24-hour periods are usually very small, but in work experiments, and especially during short periods, there may be very large variations. In this particular experiment there happened to be simply a small but a continual diminution in the amount of carbon dioxid residual in the air of the chamber, varying from 2.02 to 2.66 grams per day. The total amount of carbon dioxid exhaled by the subject, which is the algebraic sum of the quantities in columns *b* and *c*, is shown in column *d*.

For use in the experiments the data are expressed in grams, but for computation of the respiratory quotient, and for discussion of the ventilation, the volume of carbon dioxid in liters is desirable, as given in column *e*. These figures were obtained by multiplying those in column *d* by the factor 0.5091, which represents the ratio between the weight and the volume of carbon dioxid. The quantities of carbon in the carbon dioxid exhaled by the subject given in column *f*, are obtained by multiplying the figures in column *d* by the factor 3/11. These data are used in subsequent calculations of gains or losses of chemical elements and compounds by the body.

AMOUNT OF OXYGEN CONSUMED.

The amount of oxygen consumed by the subject is computed from the data regarding the amount admitted to the chamber and the amount residual in the air of the chamber. These data for experiment No. 56 are summarized in Table 10.

TABLE 10.—*Daily record of oxygen in ventilating air current, and respiratory quotients, metabolism experiment No. 56.*

Date.	Oxygen.						(*g*)	(*h*)
	(*a*) Total amount in chamber at end of day.	Gain (+) or loss (−) over preceding day.		(*d*) Amount admitted to chamber.	(*e*) Amount consumed by subject, *d*−*c*.	(*f*) Volume consumed, *e*×0.7.	Volume of carbon dioxid exhaled.	Respiratory quotients, *g*÷*f*.
		(*b*) Volume.	(*c*) Weight, *b*÷0.7.					
1903.	*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Apr. 27–28	967.44	− 4.70	− 6.71	1,538.53	1,545.24	1,081.67	903.96	0.836
28–29	936.17	− 31.27	− 44.67	1,607.89	1,652.56	1,156.79	923.28	.798
29–30	871.62	− 64.55	− 92.22	1,425.58	1,517.80	1,062.46	864.15	.813
Total, 3 days	....	−100.52	−143.60	4,572.00	4,715.60	3,300.92	2,691.39	.815

The amounts of oxygen admitted to the chamber, given in column *d*, are determined from the loss in weight of the cylinders containing the oxygen and the analyses of the gases they contain. The total amounts residual in the chamber at the end of each day, as determined by volume from the analyses of the residual air, are given in column *a*. The variations in the amounts present from day to day are given in liters in column *b* and in grams in column *c*, the values in the latter column being computed by dividing those in the former column by 0.7. The algebraic difference between the values in columns *d* and *c* is the amount consumed by the subject.

RESPIRATORY QUOTIENT.

The ratio between the volume of carbon dioxid exhaled and that of oxygen consumed, which is commonly represented by the expression $CO_2 \div O_2$, is the so-called respiratory quotient. When pure carbon is burned in the air to carbon dioxid the volume of the latter formed is exactly equal to that of oxygen consumed—that is, there is no change in the volume. When carbohydrates are katabolized in the body the carbon is oxidized to carbon dioxid and the hydrogen to water. Since the hydrogen and oxygen in the carbohydrate molecule are in the same proportions as in water, the reaction may be considered simply as a combustion of carbon, and the volume of oxygen consumed is exactly the same as that of the carbon dioxid given off—that is, the respiratory quotient for carbohydrates is 1. In fats the amount of hydrogen in the molecule is considerably greater than the amount of oxygen, so that in the combustion both carbon and hydrogen require oxygen beyond that contained in the molecule. The water resulting from this combustion condenses, and consequently the final volume, that of carbon dioxid, is considerably less than that of oxygen absorbed. Similarly when protein is burned there is a diminution in the volume of carbon dioxid, as compared with that of oxygen, resulting from the combustion of certain amounts of organic hydrogen and the liberation of nitrogen. The respiratory quotient for proteids is not far from 0.809, and that for fats as low as 0.711.[a] The average respiratory quotient for an ordinary diet, consisting of proteids, fats, and carbohydrates, would be somewhere near 0.9.

The data necessary for the computation of the respiratory quotients in experiment No. 56 are also summarized in Table 10. The amount of oxygen consumed by the subject, which is expressed by weight in column *e*, is converted to volume in column *f*. The figures for volume of carbon dioxid exhaled, given in column *g*, are derived from column *e*, in Table 9. The respiratory quotients computed from these data are given in column *h*. The average quotient for the three days is 0.815. This is probably rather high for a diet containing such a large proportion of fat as was given in this case, though there was a considerable amount of carbohydrates in the diet—about 450 grams per day—and since the respiratory quotient for carbohydrates is 1, the effect of this material would be, of course, to raise the respiratory quotient for the whole diet considerably above that of pure fat.

AMOUNT OF HEAT ELIMINATED.

The data from which the amount of heat eliminated by the body is determined are summarized for experiment No. 56 in Table 11.

TABLE 11.—*Summary of calorimetric measurements, metabolism experiment No. 56.*

Date.	(*a*) Heat measured in terms C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, $b \times 60$.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total in outgoing air plus excess residual vapor.	(*f*) Heat used in vaporization of water, $e \times 0.592$.	(*g*) Total heat determined, $a+c+d+f$.
1903.	*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 27	4,594.50	−0.01	− 0.60	− 37.97	1,248.60	739.17	5,295.10
28	4,657.59	+ .28	+16.80	− 42.33	1,353.70	801.35	5,433.41
29	4,443.16	− .20	−12.00	− 44.33	1,245.00	737.05	5,123.88
Total, 3 days	13,695.25	+07	+ 4.20	−124.63	3,847.30	2,277.57	15,852.39

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 170.

As has been previously explained (p. 35), the major portion of the heat given off by the body of the subject in the respiration calorimeter is absorbed by the water flowing through the device which has been designated as the heat absorber. From the weight of water passing through the absorber and its rise in temperature the amount of heat removed from the chamber is determined. Since the standard calorie used in these investigations is that at 20°, the computation of the amount of heat brought away by the water is reduced to terms of calories at 20°. To do this, allowance is made for the difference in the specific heat of water at different temperatures. The results of these computations are given in column *a*.

A considerable portion of heat given off by the subject is rendered latent by the evaporation of water of respiration and perspiration, and is carried out of the chamber as latent heat of water vapor in the air current. The amount of water vapor thus carried out is shown in column *e*, which is derived from the data in Table 9. The amount of heat absorbed in vaporizing this amount of water and thus removed from the chamber is ascertained by multiplying the quantities in column *e* by the factor 0.592, which represents the amount of heat necessary to vaporize 1 gram of water at 20°. The results of this computation are given in column *f*.

In spite of the greatest care on the part of the observers to regulate the amount of heat brought away from the chamber so that it will be exactly parallel with that liberated by the subject, there are unavoidable small fluctuations in the temperature of the calorimeter itself, which means that there is a certain amount of heat absorbed by the walls of the chamber or radiated from them. These fluctuations in temperature are shown in column *b*, a rise being indicated by a plus sign and a fall by a minus sign. From the results of tests it has been estimated that the hydrothermal equivalent of the mass of material of which the calorimeter chamber is composed is not far from 60 calories. The absolute value is somewhat uncertain, but it is probable that for the small temperature changes that occur in these experiments the value given is sufficiently accurate for all practical purposes. The fluctuations in temperature given in column *b*, multiplied by 60, give the quantity of heat in calories for which allowance must be made for the heat gained or lost by the metal of the calorimeter. This value, which is known as the capacity correction, is given in column *c*.

Commonly the temperature of some items of the diet sent into the calorimeter is different from that of the chamber itself; such materials as drinking water, milk, etc., being invariably colder, and coffee or tea, meat extract, and the like, usually warmer than that of the chamber. It is therefore necessary to make allowance for the amount of heat introduced or absorbed by the food and drink and their containers, which is computed from the difference in temperature at which the material is sent into the chamber and the specific heat of the substance introduced. The results of this computation are given in column *d*.

The total quantity of heat determined, column *g*, is the algebraic sum of the results in columns *a*, *c*, *d*, and *f*. Inasmuch as any gain or loss of heat by the walls is prevented (with the exception of the small amount for which allowance has been made as explained above), and the ingoing air is warmed or cooled to the same temperature as that of the outgoing air, so that gain or loss of heat in this way is also prevented, the total heat determined, as expressed in column *g*, may be assumed to represent that actually eliminated by the subject during the day. This value, however, may or may not be the same as that for heat produced during the day. In determining the heat production it is necessary to take into consideration fluctuations in body temperature and body weight and changes in the temperature of the bed and bedding, as elsewhere explained. (See p. 191.)

COMPARISON OF INCOME AND OUTGO OF MATERIAL AND ENERGY.

From the data given in the preceding tables the amounts of material and energy received and given off by the body in different ways may be compared, and the gain or loss by the body estimated. Such a comparison is made in the tables which follow. Inasmuch as the method of estimating gain or loss of body material differs rather decidedly from that employed in experiments reported in previous bulletins, a somewhat detailed explanation seems advisable here.

Gain or Loss of Body Material.

The computation of the amounts of materials gained or lost by the body for all the experiments here reported is given in detail in Table 118 of the Appendix. For purposes of illustration in the present explanation the data for the first day of experiment No. 56 are here tabulated.

Table 12.—*Gains and losses of body material on first day of metabolism experiment No. 56.*

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
Income.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Oxygen from air	1,545.24				1,545.24	
Water in drink	1,950.00			218.20	1,731.80	
Water in food	2,935.50			328.48	2,607.02	
Solids in food and drink	914.50	18.45	507.94	76.28	290.13	21.70
Total	7,345.24	18.45	507.94	622.96	6,174.19	21.70
Outgo.						
Water in feces	191.30			21.41	169.89	
Solids in feces	48.40	1.80	26.80	4.07	6.63	9.10
Water in urine	1,425.80			159.55	1,266.25	
Solids in urine	69.80	14.31	11.57	2.92	26.90	14.10
Water of respiration and perspiration	3,702.27	*.65		414.21	3,287.41	
Carbon dioxid of respiration	1,775.61		484.25		1,291.36	
Total	7,213.18	16.76	522.62	602.16	6,048.44	23.20
Gain (+) or loss (−)	+132.06	+1.69	−14.68	+20.80	+125.75	−1.50
Ash of protein gained	.16					
	+132.22					
Gains and losses of body material.						
Protein	+ 10.14	+ 1.69	+ 5.35	+ .71	+ 2.23	+ .16
Fat	+ 43.82		+33.35	+ 5.17	+ 5.30	
Glycogen	−120.17		−53.36	− 7.45	− 59.36	
Water	+199.93			+22.37	+177.56	
Ash	− 1.50					−1.50
	+132.22	+ 1.69	−14.66	+20.80	+125.73	−1.34

* Nitrogen of perspiration.

The income of material to the body consists of oxygen from the air and the water and solids of food and drink. The total weight of oxygen consumed by the subject is obtained from column *e* of Table 11. The quantity of water in drink is obtained from the record of the amount of drinking water consumed during the experiment, shown in Table 121 of the Appendix. The amount of water in the food, obtained from column *b* of Table 7, is the result of chemical analyses of the different food materials. The amount of solid material in the foods is determined by deducting the weight of water from the total weight of food as shown in columns *a* and *b* of Table 7.

The outgo consists of the water and solids of the excreta and the water and carbon dioxid of respiration and perspiration. The amount of water in the feces and urine is ascertained from the data in Table 7, and the amount of solid material is also derived from the same table as the difference between the amount of water and the total weight of material. The water of respiration and perspiration, as determined by means of the respiration calorimeter, is found in column *g* of Table 8. The carbon dioxid of respiration, likewise determined by the respiration apparatus, is given in column *d* of Table 9. The difference between the total weight of income and that of outgo represents the total gain or loss of material by the body. In the case here used for illustration the income was 132.06 grams greater than the outgo.

Of rather more importance, however, than the total weight of material gained or lost is the gain or loss of the different elements—nitrogen, carbon, hydrogen, oxygen, and ash. (For convenience in these computations the ash is considered as an element.) The intake of oxygen from the air is directly determined. The quantities of hydrogen and oxygen in the water of drink, food, feces, urine, and respiration are calculated from the chemical composition of water, and the quantities of carbon and oxygen in the carbon dioxid exhaled by the subject are similarly computed from the chemical composition of carbon dioxid. The weight and chemical analyses of the solids of food, feces, and urine give directly the data for computing the quantities of nitrogen, carbon, hydrogen, and ash in these different materials. The sum of the weights of these elements deducted from the total weight of material gives the quantity of oxygen by difference, since it has not yet been found practicable to determine the oxygen directly in these materials. These data are all obtained from those given in Tables 7 and 8. The nitrogen attributed to water of respiration and perspiration is that from the solid matter in perspiration as determined by analysis of the water in which the underclothing worn by the subject is washed. It is included here simply for convenience in the computations. It will be observed on comparing the total income of elements with the total outgo in Table 12 that there was a gain of 1.69 grams of nitrogen, 20.80 grams of hydrogen, and 125.75 grams of oxygen, and a loss of 14.68 grams of carbon and 1.50 grams of ash. The total gains and losses of elements by the body for each of the three days of experiment No. 56 are summarized in Table 13.

TABLE 13.—*Gains and losses of elements to the body, metabolism experiment No. 56.*

Date.	Total weight.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Ash.[a]
1903.						
Apr. 27-28:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Total income	7,345.24	18.45	507.94	622.96	6,174.19	21.70
Total outgo	7,213.18	16 76	522.62	602.16	6,048.44	23.20
Gain (+) or loss (−)	+132.06	+1.69	− 14.68	+20.80	+125.75	−1.50
Ash of protein gained	+ .16					
	+132.22					
Apr. 28-29:						
Total income	7,502.56	18.68	518.42	628.41	6,315.05	22.00
Total outgo	7,206.04	17.94	533.92	600.07	6,035.91	18.20
Gain (+) or loss (−)	+296.52	+ .74	− 15.50	+28.34	+279.14	+3.80
Ash of protein gained	+ .07					
	+296.59					
Apr. 29-30:						
Total income	7,427.80	18.95	531.00	634.97	6,220.48	22.40
Total outgo	6,803.33	19.62	503.67	568.45	5,693.49	18.10
Gain (+) or loss (−)	+624.47	−.67	+ 27.33	+66.52	+526.99	+4.30
Ash of protein lost	− .06					
	+624.41					

[a] Ash considered as an element.

METHOD OF COMPUTING THE AMOUNTS OF COMPOUNDS GAINED OR LOST BY THE BODY.

In the lower section of Table 12 are shown the amounts of protein, fat, carbohydrates, and water gained or lost by the body on the first day of experiment No. 56, as computed from the gains or losses of elements. The gains or losses of these different compounds are computed by means of formulæ derived from the following data regarding elementary composition of these compounds:

TABLE 14.—*Assumed percentage composition of body materials.*

	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per ct.*
Protein	16.67	52.80	7.00	22.00	1.53
Fats	....	76.10	11.80	12.10	....
Carbohydrates	....	44.40	6.20	49.40	....
Water	....	....	11.19	88.81	....

As a result of a large number of analyses, Kohler [a] has found that animal proteid—i. e., water-free, fat-free, and ash-free muscle—contains 16.67 per cent of nitrogen. The values for the percentages of carbon, hydrogen and mineral materials of protein are derived from the average of a number of analyses of animal proteids by different investigators. Doubtless these figures do not correspond with the exact composition of any particular animal proteid, but they probably are not far from the average for body proteid in general. The sum of these proportions subtracted from 100 represents the percentage of oxygen by difference in protein. The proportions of carbon and hydrogen in fat are those found by Benedict and Osterburg [b] from a number of analyses of human fats made in the laboratory at Middletown. The proportion of oxygen was computed by difference. The carbohydrates in the body are assumed to have the composition of glycogen. The chemical composition of water is, of course, accurately known. It is included in Table 15 simply for the sake of completeness.

The ash of protein may be disregarded, and the following equations may be derived from the above data, letting p = protein, t = fat, r = carbohydrates, and w = water, and indicating the names of the elements by the initial letter, as is customary:

$$\begin{aligned} 0.1667\,p &= \mathrm{N} \\ 0.4440\,r + 0.7610\,t + 0.5280\,p &= \mathrm{C} \\ 0.1119\,w + 0.0620\,r + 0.1180\,t + 0.0700\,p &= \mathrm{H} \\ 0.8881\,w + 0.4940\,r + 0.1210\,t + 0.2200\,p &= \mathrm{O} \end{aligned}$$

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[a] Ztschr. Physiol. Chem., 31 (1901), p. 498.

[b] Amer. Jour. Physiol., 4 (1900), p. 74.

The solution of these equations in terms of nitrogen, carbon, hydrogen, and oxygen gives the following formulæ:

$$\begin{array}{l}
\text{Protein} = 6.0\ \text{N} \\
\text{Fat} = 0.005\ \text{C} + 9.693\ \text{H} - 1.221\ \text{O} - 2.476\ \text{N} \\
\text{Carbohydrates} = 2.243\ \text{C} - 16.613\ \text{H} + 2.093\ \text{O} - 2.892\ \text{N} \\
\text{Water} = -1.248\ \text{C} + 7.920\ \text{H} + 0.128\ \text{O} + 0.460\ \text{N}
\end{array}$$

If the quantity of each element gained or lost by the body as expressed in grams in Table 13 is substituted in these equations for the corresponding sign of the element and the indicated calculations are performed, the results obtained will be the quantities of the different compounds gained or lost. These computations are here illustrated by use of the data for the first day of experiment No. 56.

For example, according to Table 13, the body gained 1.69 grams of nitrogen on the first day of the experiment. This value would therefore be substituted for N in the first of the above equations as follows:

$$\begin{aligned}
\text{Protein} &= 6\ \ \text{N} \\
&= 6\ \ (+1.69) \\
&= +10.14
\end{aligned}$$

which simply means that 6 times the quantity of nitrogen gained represents the quantity of protein gained.

In the case of fats the gains and losses of all four elements must be used in the computation as follows:

$$\begin{array}{lllll}
\text{Fat} = & +0.005\ \text{C} & +9.693\ \text{H} & -1.221\ \text{O} & -2.476\ \text{N} \\
= & +0.005\ (-14.68) & +9.693\ (+20.80) & -1.221\ (+125.75) & -2.476\ (+1.69) \\
= & -0.073 & +201.614 & -153.541 & -4.184 \\
= & +43.82 & & &
\end{array}$$

For C is substituted -14.68; for H $+20.80$; for O $+125.75$, and for N $+1.69$. Performing the indicated mathematical operations gives -0.073, $+201.614$, -153.541 and -4.184 to be added algebraically. The sum 43.82 is the number of grams of fat gained or lost by the body. In this case the sign is plus, indicating that there was a gain of fat.

In a similar way the weights of the different elements are substituted for their signs in the formulæ for glycogen and water and the operations performed give the gain or loss of glycogen and water as follows:

$$\begin{array}{llllll}
\text{Glycogen} & = & +2.243\ \text{C} & -16.613\ \text{H} & +2.093\ \text{O} & -2.892\ \text{N} \\
 & = & +2.243\ (-14.68) & -16.613\ (20.80) & +2.093\ (125.75) & -2.892\ (1.69) \\
 & = & -32.927 & -345.550 & +263.195 & -4.887 \\
 & = & -120.17 & & & \\
\text{Water} & = & -1.248\ \text{C} & +7.920\ \text{H} & +0.128\ \text{O} & +0.460\ \text{N} \\
 & = & -1.248\ (-14.68) & +7.920\ (20.80) & -0.128\ (125.75) & +0.460\ (1.69) \\
 & = & +18.321 & +164.736 & +16.096 & +0.777 \\
 & = & +199.93 & & &
\end{array}$$

The gains and losses of protein, fat, glycogen, and water as thus computed from the gains and losses of elements for the first day of experiment No. 56 are shown in the lower section of the first column of Table 12. The quantities of nitrogen, carbon, hydrogen, and oxygen in these materials may be then computed by means of the percentage composition given in Table 14. The sum of the quantities of each element thus computed should agree with the difference between the income and outgo of the same element shown in the upper portion of the table. It is to be borne in mind, however, that this agreement is nothing more than a mathematical verification of the accuracy of the results of the computations.

POSSIBILITIES OF ERROR IN THE RESULTS.

There are some possibilities of error in the results computed according to the method just described and these should be considered here, inasmuch as this is the first detailed account of this method of computing the gains and losses of body material in the metabolism experiments with the respiration calorimeter.

In the first place, the four formulæ are derived from the values for percentage composition of compounds supposed to represent the protein, fat, carbohydrates, and water of the body. The composition of water is, of course, accurately known, and the values used for the other compounds probably represent fairly well the average composition of these as they occur in the body, though it is to be remembered that they are approximate and not absolute. The coefficients of the different quantities in the formulæ are therefore reasonably satisfactory, though subject to revision as knowledge regarding the nature of the body compounds accumulates.

In the second place, it is necessary to substitute in the formulæ certain values for the gains and losses of the elements, nitrogen, carbon, hydrogen, and oxygen, which are determined in part directly from the analyses of the food, feces and urine, and respiratory products, and in part indirectly, as in the case of the estimation of the amount of oxygen in the compounds of the food and excreta. Of these determinations that of nitrogen is perhaps the most accurate. The errors affecting that of carbon and hydrogen have been in large part eliminated, although it is a well-known fact that the method followed in the determination of organic hydrogen almost invariably gives results that are somewhat too high rather than too low. Furthermore, since the majority of these determinations are made with partially dried samples, there is another possibility of error in the determination of the amount of water present in the partially dried material. The percentage of carbon is not affected by inaccuracy in this determination, but to ascertain the quantity of organic hydrogen it is essential to know the exact amount of preformed water present. The difficulties attending the determination of the amount of water in compounds dealt with in experiments of this kind have been mentioned on page 46.

In the different formulæ for computing the gains or losses of body materials, the highest coefficient for carbon is 2.243, the highest for oxygen, 2.093, while for organic hydrogen the highest is 16.613 and the lowest, 7.920. In other words, any error in the determination of organic hydrogen is multiplied by a large factor, thus necessitating unusual accuracy in the determination of this element. It is perhaps fortunate that in the computation of the gains or losses of material an error in the organic hydrogen results in an increased value in the case of fat and water, and a diminished value in the case of carbohydrates. This tendency toward compensation undoubtedly diminishes to a certain extent the final effect of an error in the hydrogen determination, but the results obtained by use of these formulæ for computing the gains or losses of body material are open to criticism.

With advance in experimental methods and additional knowledge of the exact nature of the materials of which the body is composed, it may be possible to eliminate still further the errors in these computations. However, they represent the most accurate method of estimating the gains or losses of the four compounds—protein, fat, carbohydrates, and water—that, so far as we are aware, has as yet been suggested.

AMOUNTS OF BODY MATERIAL GAINED OR LOST.

The amounts of the different compounds gained or lost by the body in all three days of experiment No. 56, as computed from the gains or losses of elements in the manner just explained, are shown in Table 15. For convenience in later calculations, the results of these computations have been given to the second decimal place, both here and in the corresponding tables of the experiments reported beyond. From what has been explained above regarding the possible error in the determination of organic hydrogen, the second decimal place seems not significant; indeed it is probable that the first is without value. In the mathematical verification of the results, however, the second decimal places are of service.

TABLE 15.—*Gains and losses of compounds to the body, metabolism experiment No. 56.*

Date.	Protein.	Fat.	Carbohydrates.	Water.
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 27-28	+10.14	+43.82	−120.17	+ 199.93
28-29	+ 4.44	−68.04	+ 76.52	+ 279.87
29-30	− 4.02	+ 3.12	+ 61.14	+ 559.87
Total, 3 days	+10.56	−21.10	+ 17.49	+1,039.67
Average per day	+ 3.52	− 7.03	+ 5.83	+ 346.56

During this experiment there was an average gain by the body of 3.52 grams of protein, 5.83 grams of carbohydrates, and 346.56 grams of water per day, with a loss of 7.03 grams of fat. These results show a fairly uniform body condition at the beginning and end of each experiment—that is, no decided gain or less. The results for the individual days, however, indicate that there were marked fluctuations in the amounts gained or lost for the daily periods. There was a decided gain of protein on the first day, which fell off on the second day and culminated in a loss on the third day. With fat there was a gain on the first day, a loss on the second day, and approximately fat equilibrium on the third day. In the case of carbohydrates the large loss on the first day was followed by considerable gains on the second and third days.

INTAKE AND OUTPUT OF ENERGY.

Energy is taken into the body in the food and is given off as heat radiated from the body, latent heat of vaporization of water, and potential energy of the unoxidized materials of feces and urine. When such intake and output are equal, the body may be said to be in energy equilibrium. As a matter of fact, such a condition rarely occurs, but because of variations in muscular activity, by which the heat output is so largely affected, the body is drawing upon its previously stored material at one time and adding to it at another, according to whether the energy of the food is insufficient or excessive under the given conditions. It will suffice better for the purpose of the present discussion, therefore, and also be more concordant with the previous established custom in connection with these experiments, to consider the income of energy as the energy from material actually katabolized in the body, including both food and body material.

The outgo of energy is that given off by the body as heat and external muscular work, which in these experiments is also measured in terms of heat, the total output being therefore the amount of energy (heat) actually measured by the respiration calorimeter. A comparison of the income and outgo of energy on the several days of experiment No. 56 is shown in Table 16.

Table 16.—*Income and outgo of energy, metabolism experiment No. 56.*

Date.	Heat of combustion of food and excreta as determined by use of bomb calorimeter.			(*d*) Available energy from food, $d=a-(b+c)$.	Heat of combustion of body material gained (+) or lost (−) as calculated by use of factors.*			(*h*) Total energy from body material gained (+) or lost (−), $e+f+g$.	(*i*) Estimated energy from material oxidized in the body, $d-h$.	(*k*) Heat measured by the respiration calorimeter.	Heat measured greater (+) or less (−) than heat estimated.	
	(*a*) Food.	(*b*) Feces.	(*c*) Urine.		(*e*) Protein.	(*f*) Fat.	(*g*) Carbohydrates.				(*l*) Amount, $k-i$.	(*m*) Proportion $l \div k$.
1903.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*P. ct.*
Apr. 27	5,548	309	147	5,092	+57	+418	−504	− 29	5,121	5,295	+174	+3.3
28	5,549	309	130	5,110	+25	−649	+321	−303	5,413	5,433	+ 20	+ .4
29	5,599	309	138	5,152	−23	+ 30	+256	+263	4,889	5,124	+235	+4.6
Total, 3 days	16,696	927	415	15,354	+59	−201	+ 73	− 69	15,423	15,852	+429	......
Average per day	5,565	309	138	5,118	+20	− 67	+ 24	− 23	5,141	5,284	+143	+2.7

* Protein 5.65, fat 9.54, and glycogen 4.19 calories per gram.

Since not all the food is oxidized, a considerable amount of incompletely oxidized material being excreted, the available energy from the food may be considered as the potential energy of the total food ingested, less that of the solid material of the feces and urine excreted. The potential energy of the food and excretory products, as actually determined by means of the bomb calorimeter, is shown in columns *a*, *b*, and *c*, and the available energy of the food in column *d*. Thus, on the first day of experiment No. 56, the total potential energy of the food was 5,548 calories, and that of the excreta was 456 calories, leaving 5,092 calories as the amount of energy actually available from the food.

This amount of energy may have been larger or smaller than that expended by the body, the difference being the energy of material gained or lost by the body. From the amounts of protein, fat, and carbohydrate gained or lost by the body, as shown in Table 15, the amount of energy thus gained or lost is computed by means of certain factors which have been assumed for the heat of combustion per gram of the particular body material as a result of a large number of the heats of combustion of proteids, fats, and glycogen. The heat of combustion of protein, 5.65 calories per gram, is that of fat-free muscular tissue from which the nonproteid nitrogenous compounds have not been removed. Several determinations of the heat of combustion of fat from the human body have been made in this laboratory; an average of the results shows that each gram of fat liberates approximately 9.54 calories of heat when oxidized. The heat of combustion of glycogen has been determined to be 4.19 calories per gram. The quantities of energy in the protein, fat, and carbohydrate gained or lost by the body, as computed by means of these factors, are shown in columns *e*, *f*, and *g*, and their algebraic sum, representing the total energy from body material gained or lost, in column *h*. On the first day of experiment No. 56 the body gained protein enough to supply 57 calories and fat enough to supply 418 calories, but it lost glycogen enough to supply 504 calories. The total amount of energy from body material lost was therefore 29 calories greater than that from material gained. Since this quantity is subtracted algebraically from that in column *d*, it is actually added, and the total energy from material oxidized in the body is larger than that available from the food. The quantity of energy in column *h*, subtracted algebraically from that in column *d*, gives the amount of energy estimated to have been derived from material actually oxidized in the body, as shown in column *i*. The heat measured by the respiration calorimeter, given in column *k*, should agree with the quantity in column *i*. The actual differences between these two sets of figures are given in column *l*, and the percentage difference in the last column of the table. In this particular experiment the proportionate difference ranged from 0.4 per cent to 4.6 per cent, the average difference for the three days being 2.7 per cent. The large error in this case is exceptional. The average error of 2.7 per cent is not indeed of great magnitude in a physiological experiment, but it is larger than has seemed desirable in these investigations with the calorimeter. Since this was the first experiment with the apparatus in its revised form, some discrepancy was not altogether unexpected, but it was believed that with improvements in methods and technique an agreement between the measured energy and that estimated to have been expended by the body would be closer than that found in this case.

METABOLISM EXPERIMENT NO. 57.

It was found impracticable to follow experiment No. 56, in which the subject was given a fat diet, immediately by experiment No. 57, with a carbohydrate diet. An interval of three days elapsed between the end of the former experiment and the customary preliminary digestion period of four days, which began with breakfast of May 3, 1903. The subject entered the respiration chamber at 10 p. m. of the evening of May 6, and experiment No. 57 began at 7 a. m. the following morning, continuing until 7 a. m. of May 9.

As the subject had but shortly before finished experiment No. 56, he was in training so far as riding on the bicycle ergometer was concerned, and during both the preliminary digestion experiment and the metabolism experiment proper he rode the ergometer for about 6 hours and 30 minutes per day.

Inasmuch as this experiment was intended to be a duplicate of experiment No. 53 of the preceding year, the diet was so arranged as to include practically the same materials in similar proportions as used in that experiment. Some fat was unavoidable in the diet, since it was necessary to include a considerable volume of milk in order to render the rather dry ration more palatable, but the amount of fat was purposely kept at a minimum, about 85 grams per day. A large quantity of carbohydrates, averaging a little over 1,000 grams per day, was used to supply energy for muscular work, which in experiment No. 56 had been largely derived from fat. The use of milk sugar, which had previously been tried with considerable success in experiments of this nature, was here continued, the diet containing 100 grams per day. The fact that milk sugar is not quite as sweet as cane sugar seemed to make it somewhat better relished by the subjects. During this experiment the subject experienced no difficulty in consuming all of the ration.

The total energy of the ration amounted to about 5,500 calories, of which the carbohydrates furnished about 4,000, or nearly 80 per cent of the total. The carbohydrate diet therefore more nearly represents a ration consisting of but one nutrient than did the fat diet of experiment No. 56, since in that case not over 60 per cent of the total energy of that diet could be administered in fat.

Daily programme.—The importance of having the muscular activity alike during both experiments was such as to cause all precautions to be taken not only to equalize as nearly as possible the activity on the different days of the experiment, but also to approximate as closely as possible the conditions of experiment No. 56. The programme was therefore exactly that given for experiment No. 56 on page 57.

The composition of food, feces, and urine.—The percentage composition and the heat of combustion per gram of the food, feces, and urine of experiment No 57 are given in Table 17.

TABLE 17.—*Percentage composition and heat of combustion per gram of food, feces, and urine, metabolism experiment No. 57.*

Laboratory No.	Kind of material.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion per gram.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cals.*
3637	Ginger snaps	7.5	5.2	9.0	75.9	2.4	0.91	42.41	6.14	4.244
3638	Shredded wheat	8.2	9.7	1.7	78.8	1.6	1.70	41.32	5.65	4.021
3648	Graham crackers	5.9	6.5	9.2	76.2	2.2	1.14	43.06	6.29	4.366
3649	Bread	42.2	7.7	1.3	47.8	1.0	1.35	26.28	3.90	2.613
3655	Cereal coffee	99.4	.1	......	.5	......	[a].01	[a].47	[a].07	.026
3650	Butter	9.4	1.2	85.9	......	3.5	.17	64.45	10.03	7.903
	Milk sugar [b]	5.1	......	......	94.9	......	......	40.00	6.15	3.719
	Cane sugar [b]	......	......	......	100.0	......	......	42.10	6.48	3.960
3652	Milk [b]	85.6	3.8	4.5	5.3	.8	.61	7.83	1.19	......
3654	Feces	85.1	5.2	2.0	5.5	2.2	.83	7.21	.99	.765
	Urine, first day [b]	94.2	......	......	......	1.3	1.33	1.08	.29	.122
	Urine, second day [b]	94.2	......	......	......	1.3	1.79	1.45	.38	.152
	Urine, third day [b]	94.2	......	......	......	1.3	1.85	1.50	.39	.158

[a] Estimated from previous analyses.

[b] See explanation on p. 79.

The chemical composition of the milk sugar was computed from the molecular weight, including one molecule, or 5.1 per cent, of water of constitution. Cane sugar was assumed to be 100 per cent carbohydrates. There are slight impurities in the best grades of commercial cane sugar, such as small quantities of nitrogen and ash, and there is furthermore a tendency toward a retention of hygroscopic water, but we have been accustomed to assume that both milk and cane sugars have compositions represented by their molecular formulæ, because the errors in such assumption are all within the limit of error in physiological experimenting.

Milk from two lots was used each day, that delivered at the laboratory in the morning being used at dinner and supper of the same day and at breakfast of the next day, thus making four lots of milk for the three days. The heat of combustion was determined for each lot, but a composite sample containing an aliquot portion of each was used for the chemical analysis.

The proportion of nitrogen and the heat of combustion per gram of the urine were determined each day; the proportions of carbon and hydrogen were determined in a composite sample for three days, and apportioned among the different days in accordance with the elimination of nitrogen. This was not done in the case of water, consequently there is a slight but insignificant error in the water data of the urine for the separate days.

The weights of the different food materials consumed, and the quantities of compounds, elements, and energy supplied by them are shown in Table 18, and the corresponding data for the feces and urine are included in the same table.

TABLE 18.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiment No. 57.*

Laboratory No.	Kind of material.	(*a*) Total weight.	(*b*) Water.	Water-free substance. (*c*) Protein.	(*d*) Fat.	(*e*) Carbohydrates.	(*f*) Ash.	(*g*) Nitrogen.	(*h*) Carbon.	(*i*) Hydrogen.	(*k*) Oxygen by difference.	(*l*) Heat of combustion.
	FOOD.											
	Basal ration.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3649	Bread	550.0	232.1	42.4	7.1	262.9	5.5	7.43	144.54	21.45	138.98	1,437
3637	Ginger snaps	85.0	6.4	4.4	7.7	64.5	2.0	.77	36.05	5.22	34.56	361
3638	Shredded wheat	120.0	9.9	11.6	2.0	94.6	1.9	2.04	49.58	6.78	49.80	483
3648	Graham crackers	100.0	5.9	6.5	9.2	76.2	2.2	1.14	43.06	6.29	41.41	437
	Milk sugar	100.0	5.1	......	......	94.9	......	......	40.00	6.15	48.75	372
3655	Cereal coffee	1,200.0	1,192.8	1.2	......	6.0	......	.12	5.64	.84	.60	31
	Total basal ration	2,155.0	1,452.2	66.1	26.0	599.1	11.6	11.50	318.87	46.73	314.10	3,121

TABLE 18.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiment No. 57*—Continued.

Laboratory No.	Kind of material.	(a) Total weight.	(b) Water.	Water-free substance.								
				(c) Protein.	(d) Fat.	(e) Carbohydrates.	(f) Ash.	(g) Nitrogen.	(h) Carbon.	(i) Hydrogen.	(k) Oxygen by difference.	(l) Heat of combustion.
	FOOD—Continued.											
	Supplemental ration.											
	First day:	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3650	Butter	20.0	1.9	.2	17.2	......	.7	.03	12.89	2.01	2.47	158
3652	Milk	1,000.0	856.0	38.0	45.0	53.0	8.0	6.10	78.30	11.90	39.70	877
	Cane sugar	350.0	......	......	......	350.0	......	......	147.35	22.68	179.97	1,386
	Total ration	3,525.0	2,310.1	104.3	88.2	1,002.1	20.3	17.63	557.41	83.32	536.24	5,542
	Second and third days, each:											
3650	Butter	10.0	.9	.1	8.6	......	.4	.02	6.45	1.00	1.23	79
3652	Milk	1,100.0	941.6	41.8	49.5	58.3	8.8	6.71	86.13	13.09	43.67	963
	Cane sugar	345.0	......	......	......	345.0	......	......	145.25	22.86	177.39	1,366
	Total ration	3,610.0	2,394.7	108.0	84.1	1,002.4	20.8	18.23	556.70	83.18	536.39	5,524
	EXCRETA.											
3654	Total feces for 3 days	1,052.4	895.6	54.7	21.0	57.9	23.2	8.73	75.88	10.42	38.57	805
	Average per day	350.8	298.5	18.2	7.0	19.3	7.7	2.91	25.29	3.47	12.86	268
	Urine, May 7–8	989.5	932.2	......	......	......	12.7	13.21	10.71	2.82	17.88	121
	Urine, May 8–9	837.6	789.1	......	......	......	10.7	14.99	12.16	3.20	7.43	127
	Urine, May 9–10	856.1	806.5	......	......	......	11.0	15.80	12.82	3.37	6.62	135
	Total urine for 3 days	2,683.2	2,527.8	......	......	......	34.4	44.00	35.69	9.39	31.93	383

The diet consisted of a basal ration, furnishing 66.1 grams of protein and 3,121 calories of energy, which was uniform on all three days, and a supplemental ration of butter, milk, and cane sugar, which increased the total ration to 104 grams of protein and 5,542 calories of energy on the first day and 108 grams of protein and 5,524 calories of energy on each of the other two days. The variation in the total ration was due to an appreciable difference in the composition of the milk.

Water eliminated.—The total water of respiration and perspiration is given in Table 19.

Table 19.—*Daily record of water of respiration and perspiration, metabolism experiment No. 57.*

Date.	(*a*) Total amount of vapor in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding day.	(*c*) Change in weight of absorbers, gain (+) loss (−).	(*d*) Amount in underclothes.*	(*e*) Total amount gained (+) or lost (−) during day, $b+c+d$.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration,* $e+f$.
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 7-8	61.27	+6.75	+2,482.20	142.00	2,630.95	1,263.81	3,894.76
8-9	58.35	−2.92	+2,510.40	160.30	2,667.78	1,523.69	4,191.47
9-10	57.52	−0.83	+2,423.20	123.80	2,546.17	1,486.61	4,032.78
Total, 3 days	....	+3.00	+7,415.80	426.10	7,844.90	4,274.11	12,119.01

* Including solids of perspiration. See explanation, p. 63.

The total amount of water eliminated was approximately the same on each of the three days, ranging from 3,894 grams on the first day to 4,191 grams on the second day. No allowance is made, however, in this experiment for alterations in weight of the bed and bedding, as such data were not available until after the new weighing device was installed, at a later date.

Carbon dioxid eliminated.—The total weight and volume of the carbon dioxid exhaled by the subject, as well as the carbon therein, are given in Table 20.

Table 20.—*Daily record of carbon dioxid in ventilating air current, metabolism experiment No. 57.*

Date.	Carbon dioxid.					(*f*)
	(*a*) Total amount in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding day.	(*c*) Total amount absorbed from outcoming air.	(*d*) Amount exhaled by subject, $b+c$.	(*e*) Volume exhaled by subject, $d \times 0.5091$.	Carbon in carbon dioxid exhaled, $d \times \frac{3}{11}$.
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
May 7-8	50.94	+11.99	2,080.89	2,092.88	1,065.50	570.79
8-9	28.15	−22.79	2,011.59	1,988.80	1,012.50	542.39
9-10	28.79	+ .64	1,952.37	1,953.01	994.28	532.63
Total, 3 days	....	−10.16	6,044.85	6,034.69	3,072.28	1,645.81

The total amount of carbon dioxid exhaled ranged from 2,092 grams on the first day to 1,953 grams on the third day.

Oxygen consumed.—The quantities of oxygen derived by the subject from the ventilating air current, and the respiratory quotients, are given in Table 21.

TABLE 21.—*Daily record of oxygen in ventilating air current and respiratory quotients, metabolism experiment No. 57.*

Date.	Oxygen.						(*g*)	(*h*)
	(*a*) Total amount in chamber at end of day.	Gain (+) or loss (−) over preceding day.		(*d*) Amount admitted to chamber.	(*e*) Amount consumed by subject, *d*−*c*.	(*f*) Volume consumed, *e*×0.7.	Volume of dioxid exhaled.	Respiratory quotients, *g*÷*f*.
		(*b*) Volume.	(*c*) Weight, *b*÷0.7.					
1903.	*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
May 7-8	990.95	− 34.31	− 49.01	1,559.75	1,608.76	1,126.10	1,065.50	0.946
8-9	923.22	− 67.73	− 96.76	1,466.07	1,562.83	1,094.00	1,012.50	.926
9-10	878.28	− 44.94	− 64.20	1,492.59	1,556.79	1,089.80	994.28	.912
Total, 3 days	....	−146.98	−209.97	4,518.41	4,728.38	3,309.90	3,072.28	....

The amount of oxygen used by the subject was large, and there was a not inconsiderable amount withdrawn from the chamber, since there was a steady loss in the residual oxygen from day to day. The largest amount of oxygen consumed by the subject was on the first day, 1,608 grams, and the smallest amount on the last day, 1,556 grams. This corresponds to the fluctuations in the carbon dioxid exhaled, as noted in the previous table. The respiratory quotients vary from 0.946 on the first day to 0.912 on the third day.

Calorimetric measurements.—The calorimetric measurements showing the elimination of heat by the subject, which are given in detail in Table 116 in the Appendix, are summarized in Table 22.

TABLE 22.—*Summary of calorimetric measurements, metabolism experiment No. 57.*

Date.	(*a*) Heat measured in terms C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b*×60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total in outgoing air plus excess residual vapor.	(*f*) Heat used in vaporization of water, *e*×0.592.	(*g*) Total heat determined, *a*+*c*+*d*+*f*.
1903.	*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
May 7	4,896.48	−0.26	−15.60	− 50.70	1,270.60	752.20	5,582.38
8	4,495.52	+ .40	+24.00	− 42.10	1,520.80	900.30	5,377.72
9	4,502.39	− .03	− 1.80	− 36.20	1,485.80	879.60	5,343.99
Total, 3 days	13,894.39	+ .11	+6.60	−129.00	4,277.20	2,532.10	16,304.09

The total amount of heat determined was greatest on the first day, while on the two remaining days it was practically constant. This would correspond to the increased volume of oxygen consumed and carbon dioxid eliminated, as previously mentioned.

Gains and losses of elements.—The data regarding the gains and losses of elements by the body, given in detail in Table 118 of the Appendix, are here summarized.

TABLE 23.—*Gains and losses of elements to the body, metabolism experiment No. 57.*

Date.	Total weight.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Ash.[a]
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 7–8:						
Total income	7,424.76	17.63	557.41	598.18	6,231.24	20.30
Total outgo	7,328.58	16.76	606.79	579.83	6,104.79	20.41
Gain (+) or loss (−)	+96.18	+.87	−49.38	+18.35	+126.45	−.11
Ash of protein gained	+ .08					
	+96.26					
May 8–9:						
Total income	7,463.83	18.23	556.70	607.51	6,260.59	20.80
Total outgo	7,369.31	18.54	579.84	597.41	6,155.06	18.46
Gain (+) or lost (−)	+94.52	−.31	−23.14	+10.10	+105.53	+2.34
Ash of protein loss	− .03					
	+94.49					
May 9–10:						
Total income	7,457.79	18.23	556.70	607.51	6,254.55	20.80
Total outgo	7,193.33	19.35	570.74	581.77	6,002.77	18.70
Gain (+) or lost (−)	+264.46	−1.12	−14.04	+25.74	+251.78	+2.10
Ash of protein loss	− .10					
	+264.36					

[a] Ash considered an element.

Gains or losses of compounds.—The gains or losses of body material in terms of protein, fats, carbohydrates, and water, as computed from the gains or losses of elements in the manner described on page 71, are summarized in Table 24.

TABLE 24.—*Gains and losses of compounds to the body, metabolism experiment No. 57.*

Date.	Protein.	Fat.	Carbohydrates.	Water.
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 7	+5.22	+21.07	−153.47	+223.55
8	−1.86	−30.30	+ 2.06	+122.23
9	−6.72	−55.22	+ 71.10	+253.10
Total, 3 days	−3.36	−64.45	− 80.29	+598.88
Average per day	−1.12	−21.48	− 26.76	+199.63

There was a slight gain of protein on the first day and an increasing loss on the subsequent days. The gain of 21 grams of fat the first day was more than compensated by a considerable loss on the second and last days. On the other hand, a large loss of carbohydrates on the first day was partially compensated by a gain on the second and last days. There was a gain of water on all three days.

Intake and output of energy.—From the determinations of potential energy of the food, feces, and urine, and the computed gains or losses of energy of body material stored or lost, the balance of income and outgo of energy is shown in Table 25.

TABLE 25.—*Income and outgo of energy, metabolism experiment No. 57.*

Date.	Heat of combustion of food and excreta as determined by use of bomb calorimeter.			(d) Available energy from food, $d=a-(b+c)$.	Heat of combustion of body material gained (+) or lost (−) as calculated by use of factors.*			(h) Total energy from body material gained (+) or lost (−), $e+f+g$.	(i) Estimated energy from material oxidized in the body, $d-h$.	(k) Heat measured by the respiration calorimeter.	Heat measured greater (+) or less (−) than heat estimated.	
	(a) Food.	(b) Feces.	(c) Urine.		(e) Protein.	(f) Fat.	(g) Glycogen.				(l) Amount, $k-i$.	(m) Proportion, $l+k$.
1903.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*P. ct.*
May 7	5,542	268	121	5,153	+29	+201	−643	−413	5,566	5,582	+16	+0.3
8	5,529	268	127	5,134	−10	−289	+ 9	−290	5,424	5,378	−46	− .8
9	5,524	268	135	5,121	−38	−527	+298	−267	5,388	5,344	−44	− .8
Total, 3 days	16,595	804	383	15,408	−19	−615	−336	−970	16,378	16,304	−74	......
Average per day	5,532	268	128	5,136	− 6	−205	−112	−323	5,459	5,435	−24	− .4

* Protein 5.65, fat 9.54, and glycogen 4.19 calories per gram.

There was a considerable draft upon body material throughout this whole experiment, averaging 323 calories per day. The agreement between the estimated energy from the material oxidized in the body and the heat measured by the calorimeter is much closer than in the experiment preceding, varying from 0.8 per cent to 0.3 per cent. For the three days the discrepancy between the two figures is but 24 calories or 0.4 per cent.

METABOLISM EXPERIMENT NO. 58.

The particular object of this experiment was a study of the transformations of matter and energy in the body, with little exercise and with a simple and restricted diet.

The subject, H. F., was a man 54 years old, who for a number of years has frequently lived for longer or shorter periods upon a diet with comparatively little variety and supplying nutritive material in small quantities. He also gives much attention to thorough mastication. His weight in underclothing and shoes was 72 kilograms (158 pounds). He appeared to be in excellent health, and previous tests, reported by Chittenden,[a] had indicated that his muscular strength and powers of endurance were such as are more common with young athletes than with men past middle age.

The preliminary feeding period began with Saturday, November 7, 1904, and continued for three days, the diet being similar to that of the metabolism experiment itself. The subject entered the calorimeter on Monday evening at 9.45 p. m., and the metabolism experiment began the following morning at 7 a. m., continuing until 7 a. m. Friday, November 13.

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[a] Pop. Sci. Mo., 63 (1903), p. 123.

The diet consisted simply of whole milk, maple sugar, and one of the common "ready-to-eat" breakfast cereals, said to be prepared from coarsely ground unbolted wheat, with an admixture of barley malt, made into flakes and cooked. As shown by the details given later, the quantity of food eaten contained barely 40 grams of total protein and 1,500 calories of energy per day. In planning the ration the subject was inclined to prefer smaller quantities, hardly more than enough to supply 900 or 1,000 calories of energy daily. As a matter of fact he did not care to have any regulated quantity of food, being accustomed to suit the quantity of food eaten, as he believed, to the dictates of his appetite; but the amount suggested seemed to him to be more than enough to meet the needs of his body, as they would be interpreted by his appetite, so far as he could tell in advance. However, it was explained that if he began with so little he would probably suffer a considerable loss of body material and would feel the need of more before the termination of the experiment; and as it was desired to avoid changing the diet after the experiment had begun, he acquiesced in the amount of food suggested. He also agreed to follow the usual custom of the experiments with regard to eating practically the same total amount of food each day, but his desire to be unrestricted as to time of eating was granted and he was allowed to take his food at such times between rising and retiring as best suited his appetite.

Programme.—Since in his daily life the subject made no attempt at regularity in hours of eating or sleeping, or in his habits in general, they did not readily conform to a programme. In order that his sojourn in the calorimeter might be as comfortable and agreeable to him as it had been to others, no régime was prescribed other than that the total food eaten between 7 a. m. and 11 p. m. was to be approximately the same from day to day, as explained above. Inasmuch as the subject endeavors to exercise control over his physical and mental status, he was asked to restrict his activity as much as possible, as this was to be a rest experiment.

In order that there might be some definite information regarding his bodily activity, a record was kept of his movements during the three days. Even in ordinary experiments the observer at the table in front of the window of the calorimeter makes such records, but they are confined chiefly to variations in the major movements from those prescribed. In this case he was instructed to note both the major and the minor movements. A transcript of the notes as recorded rather informally by the observer is here given. It will be observed that the records do not cover the periods of sleep at night, because the subject then has a black curtain in the window, thus obstructing the view of the chamber from the outside.

TABLE 26.—*Record of muscular movements, metabolism experiment No. 58.*

	November 10.
4 a. m.	Sits up in bed, moves about, but at once lies down again.
6.32 a. m.	20 respirations per minute
7 a. m.	Rises and telephones.
7.02 a. m.	Retires.
7.14 a. m.	Rises and telephones; passes urine; arranges bedding and retires.
7.52 a. m.	Rises and telephones.
7.54 a. m.	Lies down.
8.06 a m.	Eyes closed.
8.12 a. m.	Lying on left side.
8.44 a. m.	16 respirations per minute.
9.16 a. m.	Turned onto back.
9.22 a. m.	Moves hands.
9.28 a. m.	Turned to right side; hand under the head
9.36 a. m.	Turned head; restless.
9.50 a. m.	Moved hands; turned onto back.
9.56 a. m.	Eyes open.
10.12 a. m.	Turned to left side.
10.32 a. m.	Moved shoulders.
10.52 a. m.	Moved arms.
11.28 a. m.	Moved toward wall.
11.38 a. m.	Moved hands.
11.44 a. m.	Turned to right side; eyes open.
11.48 a. m.	Turned to back.
12.18 p. m.	Turned to left side.
12.30 p. m.	Restless.
12.34 p. m.	Waves hands, greeting observer.
12.46 p. m.	20 respirations per minute.
1 p. m.	Rises and telephones.
1.06 p. m.	Moves about.
1.10 p. m.	Weighs himself.
1.16 p. m.	Adjusts table.
1.18 p. m.	Prepares dinner; sits on bed and reads letters.
1.56 p. m.	Weighs himself.
2 p. m.	Uses typewriter.
2.06 p. m.	Puts on pajamas; uses typewriter.
2.18 p. m.	Stops typewriting; telephones.
2.20 p. m.	Seated.
2.24 p. m.	Uses pen.
2.30 p. m.	Clears table; begins typewriting.
2.46 p. m.	Stands and telephones.
2.48 p. m.	Walks around.
2.52 p. m.	Weighs himself.
2.54 p. m.	Sits down and typewrites.
3 p. m.	Rises, removes pajamas, and weighs.
3.02 p. m.	Sits and typewrites.
3.04 p. m.	Lies down and reads.
3.36 p m.	Sits up and telephones.
3.40 p. m.	Lies down and reads.
4.24 p. m.	Stops reading; moves hands and turns to left side.
4.28 p. m.	Rises, arranges bed, and lies down on left side.
4.56 p. m.	20 respirations in 69 seconds.
6.52 p. m.	Sits up in bed; retires.
7 p. m.	Sits up and telephones.
7.04 p. m.	Telephones.
7.08 p. m.	Wipes mirror; opens food aperture.
7.10 p. m.	Eats supper.
7.24 p. m.	Stands up.
7.28 p. m.	Weighs.
7.30 p. m.	Sits and reads.
7.32 p. m.	Writes.
7.36 p. m.	Rises; then sits and reads.
11.22 p. m.	Sits up in bed; rises and puts up curtain.
	November 11.
7 a. m.	Telephones.
7.02 a. m.	Sits and writes.
7.20 a. m.	Goes to bed.
7.56 a. m.	Sits and telephones.
8 a. m.	Reads.
8.32 a. m.	Stops reading.
	November 11—Continued.
8.34 a. m.	Restless.
8.36 a. m.	Begins reading.
8.48 a. m.	Telephones.
8.50 a. m.	Moves about; telephones, reclines, and reads.
9.04 a. m.	Rises and telephones; sits and reads.
9.12 a. m.	Moves about.
9.18 a. m.	Arranges bed; reclines and writes.
9.24 a. m.	Telephones.
10.04 a. m.	Stops writing and reads.
10.36 a. m.	Writes.
10.42 a. m.	Moves about.
10.46 a. m.	Sharpens pencil; uses typewriter.
11.26 a. m.	Stops typewriting and telephones
11.32 a. m.	Typewrites.
11.36 a. m.	Stops and reads; typewrites.
11.38 a. m.	Reads and writes with pen.
11.52 a. m.	Telephones; writes.
12.06 p. m.	Telephones.
12.16 p. m.	Stops telephoning; writes.
12.38 p. m.	Stops writing; seals letter; restless.
12.44 p. m.	Moving.
12.46 p. m.	Lying down.
1 p. m.	Sits up.
1.02 p. m.	Moving.
1.04 p. m.	Lies down.
1.08 p. m.	Sits up and reads.
1.12 p. m.	Moves; puts on shoes and weighs.
1.16 p. m.	Puts on shirt; prepares dinner.
1.18 p. m.	Eats and reads.
1.46 p. m.	Rises.
1.48 p. m.	Weighs himself, then sits and writes.
1.52 p. m.	Rises, arranges bed, and lies down.
3.34 p. m.	Sits up and drinks.
3.38 p. m.	Lies down.
5.40 p. m.	Sits up and writes.
5.52 p. m.	Telephones.
6.04 p. m.	Stops telephoning.
6.06 p. m.	Arranges pillow; reclines and reads.
7 p. m.	Telephones sitting.
7.04 p. m.	Stops telephoning; reads sitting.
7.08 p. m.	Opens food aperture; eats supper.
7.26 p. m.	Sits up.
7.28 p. m.	Sits and writes.
7.36 p. m.	Reclines and reads.
9.10 p. m.	Sits.
9.12 p. m.	Eats and drinks.
9.26 p. m.	Writes.
9.28 p. m.	Stands.
9.30 p. m.	Sits.
9.32 p. m.	Stands and arranges bed.
9.34 p. m.	Curtain up.
	November 12.
7 a. m.	Telephones.
7.02 a. m.	Stops telephoning.
7.06 a. m.	Stands and dresses; sits and puts on shoes.
7.08 a. m.	Sits and writes.
7.18 a. m.	Uses typewriter.
8.02 a. m.	Telephones.
8.04 a. m.	Sits, moves about, then sits and typewrites.
8.08 a. m.	Stops typewriting and uses pen.
8.24 a. m.	Uses typewriter.
9.06 a. m.	Stops typewriting and reads.
9.12 a. m.	Rises and moves about.
9.16 a. m.	Sits and reads letters.
9.18 a. m.	Rises, then sits and reads letters.
9.22 a. m.	Telephones.
9.24 a. m.	Reads letters.

TABLE 26.—*Record of muscular movements, metabolism experiment No. 58*—Continued.

	November 12—Continued.
10.10 a. m.	Reads and writes.
10.16 a. m.	Uses typewriter.
10.52 a. m.	Eats.
11.02 a. m.	Rises, removes shirt; puts on shirt.
11.04 a. m.	Sits down and typewrites.
11.24 a. m.	Stops (typewriting) and eats.
11.26 a. m.	(Typewriting); eats.
11.28 a. m.	Stops; eats.
11.30 a. m.	Begins.
11.52 a. m.	Reads.
12.10 p. m.	Uses typewriter.
12.24 p. m.	Telephones.
12.26 p. m.	Moves about.
12.28 p. m.	Rises and telephones; goes to food aperture.
12.34 p. m.	Uses typewriter.
1.02 p. m.	Telephones.
1.14 p. m.	Stops typewriting; uses pen.
1.22 p. m.	Uses typewriter.
1.26 p. m.	Eats.
1.30 p. m.	Uses typewriter.
1.32 p. m.	Eats.
1.48 p. m.	Curtain up.
1.54 p. m.	Moving.
1.58 p. m.	Lies down.
2.10 p. m.	Rises and telephones.
2.14 p. m.	Sits up and eats.
2.20 p. m.	Uses typewriter.
2.36 p. m.	Uses pen.
2.46 p. m.	Uses typewriter.
3.10 p. m.	Uses pen.
3.18 p. m.	Telephones.
3.22 p. m.	Arranges bed; lies down.
3.32 p. m.	Telephones; sits up and reads.
3.38 p. m.	Telephones.
3.40 p. m.	Stops telephoning; moves about.
3.44 p. m.	Lies down.
3.50 p. m.	Rises and telephones.
3.54 p. m.	Lies down.
5.20 p. m.	Sits up; looks at watch; reads.
5.26 p. m.	Telephones.
5.34 p. m.	Uses typewriter.
5.40 p. m.	Weighs and sits down.
5.44 p. m.	Uses typewriter.
5.46 p. m.	Looks at watch.
5.50 p. m.	Arranges bed; reclines and reads.
5.52 p. m.	Telephones.
5.56 p. m.	Sits up.
6 p. m.	Reclines and reads.
6.16 p. m.	Still reading.
6.36 p. m.	Still reading.
7 p. m.	Sits up and drinks.
7.02 p. m.	Telephones.
7.06 p. m.	Opens food aperature.
7.08 p. m.	Eats and telephones.
7.14 p. m.	Eats.
7.20 p. m.	Stands and weighs.
7.22 p. m.	Sits and writes.
7.24 p. m.	Arranges bed; goes to bed.
8.18 p. m.	Sits up and reads.
8.22 p. m.	Reclines and reads.
8.32 p. m.	Telephones.
8.34 p. m.	Rises; fixes absorber shields, then reclines and reads.
9.32 p. m.	Rises; weighs.
9.36 p. m.	Telephones.
9.38 p. m.	Opens food aperture.
9.42 p. m.	Drinks, reclines, and reads.
10.46 p. m.	Stops reading.
10.48 p. m.	Sits up; then stands.
10.52 p. m.	Arranges bed; puts up curtain.

The more active movements of the subject consisted mainly in rising from bed, dressing, eating, taking care of the food and excreta, writing with a pen or typewriter, and occasionally taking a few steps, but a notably large portion of the day, especially on the first and second days, was spent sitting at the table reading, or lying in bed, reading or sleeping. This experiment differed from previous rest experiments, chiefly in the general irregularity of the daily routine in eating and moving about, and in the small amount of bodily activity and of food consumption. The subject was slightly more active on the second and still more on the third day than on the first. He was asked to estimate his relative muscular activity on the three days of the experiment, and without knowing the results of the heat measurements he estimated that if the muscular activity on the first day was represented by 1.00 that on the two following days would be represented by 1.33 and 1.50 respectively. As is seen later, this estimate is of value only in indicating an impression of the subject that there was slightly greater activity on the last two days.

Previous experience leads us to believe that in this particular experiment, though the irregularities made the results for the individual days less strictly comparable with each other, they did not materially affect the experiment as a whole. Apparently there was nothing in the unusual conditions to affect the normal transformations of matter and energy, and the results were such as would naturally be expected to accompany the conditions of diet and exercise.

Food, feces, and urine.—The data regarding the percentage composition and heat of combustion of the food, feces, and urine are given in Table 27.

TABLE 27.—*Percentage composition and heat of combustion per gram of food materials, feces, and urine, metabolism experiment No. 58.*

Laboratory No.	Kind of material.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion per gram.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
3701	Prepared cereal	8.9	15.3	1.4	71.5	2.9	2.68	40.76	5.81	4.002
3702	Milk..................	86.9	3.3	4.0	5.0	.8	.53	7.05	1.01	.776
3703	Maple sugar...........	11.5	....	....	87.5	1.0	....	37.24	5.70	3.432
3705	Feces..................	71.9	5.2	2.9	14.4	5.6	.83	12.99	1.78	1.386
	Urine, first day[a]......	92.3	....	....	....	1.4	1.93	1.70	.42	.178
	Urine, second day[a]....	91.8	....	....	....	1.4	2.07	1.82	.45	.185
	Urine, third day[a].....	91.7	....	....	....	1.4	2.09	1.84	.45	.182

[a] Data in part from daily samples and part from composites.

The milk was obtained fresh each day, as usual, and a composite sample for the whole experiment was prepared, consequently but one analysis is given. The determinations of the nitrogen and heat of combustion of urine were made for each day, while those of carbon, hydrogen, and ash were made upon a composite sample and apportioned among the three days on the basis of the nitrogen determination. The total weight, composition, and heat of combustion of the food, feces, and urine, for the different days of the experiment, are given in Table 28.

TABLE 28.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiment No. 58.*

Laboratory No.	Kind of material.	Total weight.	Water.	Water-free substance.								
				Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Oxygen by difference.	Heat of combustion.
	FOOD.											
	Basal ration.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3701	Prepared cereal.....	125	11.1	19.1	1.8	89.4	3.6	3.35	50 95	7 26	48 74	500
3703	Maple sugar........	150	17.3	......	......	131.2	1.5	......	55.86	8.55	66.79	515
	Total basal ration...........	275	28.4	19.1	1.8	220.6	5.1	3.35	106.81	15.81	115.53	1,015
	Supplemental ration.											
	First day											
3702	Milk..............	610	530.1	20.1	24.4	30.5	4.9	3.23	43.01	6.16	22.60	473
	Total ration....	885	558.5	39.2	26.2	251.1	10.0	6.58	149.82	21.97	138.13	1,488

TABLE 28.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiment No. 58*—Continued.

Laboratory No.	Kind of material.	Total weight.	Water.	Water-free substance.								
				Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Oxygen by difference.	Heat of combustion.
	FOOD—Continued.											
	Supplemental ration—Continued.											
	Second day:	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3702	Milk	585	508.4	19.3	23.4	29.2	4.7	3.10	41.24	5.91	21.65	454
	Total ration	860	536.8	38.4	25.2	249.8	9.8	6.45	148.05	21.72	137.18	1,469
	Third day:											
3702	Milk	680	590.9	22.4	27.2	34.0	5.5	3.60	47.94	6.87	25.19	528
	Total ration	955	619.3	41.5	29.0	254.6	10.6	6.95	154.75	22.68	140.72	1,543
	EXCRETA.											
3705	Total feces for 3 days	[a] 145.0	104.3	7.5	4.2	20.9	8.1	1.20	18.84	2.58	9.98	201
	Average per day	48.34	34.77	2.50	1.40	6.97	2.70	.40	6.28	.86	3.33	67
	Urine, Nov. 10–11	403.8	372.90	......	......	......	5.65	7.79	6.87	1.69	8.90	72
	Urine, Nov. 11–12	399.7	366.90	......	......	......	5.60	8.27	7.29	1.79	9.85	74
	Urine, Nov. 12–13	447.0	410.00	......	......	......	6.26	9.34	8.22	2.02	11.16	81
	Total urine for 3 days	1,250.5	1,149.80	......	......	......	17.51	25.40	22.38	5.50	29.91	227

[a] See statement on p. 90.

Since the same quantities of cereal and of sugar were eaten each day, while the quantity of milk varied somewhat on the different days, the cereal and sugar are considered as the basal ration, supplemented on the different days by the varying quantities of milk; but this is simply for convenience in tabulation. The energy of the total diet ranged from 1,469 calories on the second day to 1,543 calories on the third day, and the total protein from 38.4 grams on the second day to 41.5 grams on the first day. The diet is characterized by an excess of carbohydrates, and may therefore be considered as a carbohydrate ration. At least two-thirds of the total amount of energy was supplied by this nutrient.

This subject was accustomed to retain the feces much longer than is ordinarily done, several days commonly intervening between two successive defecations, as he believed that in so doing he increased the thoroughness of digestion of his food. Because of such infrequency of defecation, the customary separation of feces for the preliminary and calorimeter periods could not be made. The lampblack taken to mark the beginning of the feces pertaining to the preliminary digestion period appeared in feces passed during the period when the subject was in the calorimeter. This was the only defecation that occurred during the six days the subject was on the experimental diet. The marker taken after the close of the experimental period was passed some days later, and unfortunately the final separation of the feces was not made in this laboratory, but by the subject himself, who had in the meantime left Middletown, and the feces supposed to represent the final portion of those pertaining to the experimental diet were returned to the laboratory. Under the circumstances, therefore, we can not vouch for the accuracy of the separation, and are not certain that all the feces pertaining to the experimental diet were collected. The total amount collected for the six days was 291 grams; since no separation could be made between that pertaining to the food of the preliminary and that of the calorimeter period, one-half of the total amount was ascribed to each period.

Water eliminated.—The quantity of water of respiration and perspiration is given in Table 29.

TABLE 29.—*Daily record of water of respiration and perspiration, metabolism experiment No. 58.*

Date.	(*a*) Total amount of vapor in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) loss (−).	(*d*) Amount in underclothes.	(*e*) Total amount gained (+) or lost (−) during day, *b*−*c*−*d*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *b*+*f*.
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 10–11	50.15	+ 5.10				502.03	507.13
11–12	36.07	−14.08				842.86	828.78
12–13	35.38	− .69				817.63	816.94
Total		− 9.67				2,162.52	2,152.85

This being a rest experiment, there was no appreciable alteration in the weight of the heat absorbing system or of the underclothes, and consequently the only correction to be made to the quantity of vapor leaving the respiration chamber in the ventilating air current was for the variations in the amount of residual vapor at the end of each day. There was a marked increase in the water of respiration and perspiration on the second day, the quantity being some 300 grams larger than on the first day. On the third day the amount was not unlike that on the second. This difference in the vaporization of water may possibly be ascribed to the fact that for the greater part of the first day the subject was lying in bed covered with the bedclothes, thus retarding in considerable proportion the elimination of water through perspiration.

Carbon dioxid eliminated.—The data regarding the amount of carbon dioxid eliminated are summarized in Table 30.

TABLE 30.—*Daily record of carbon dioxid in ventilating air current, metabolism experiment No. 58.*

Date.	Carbon dioxid.					(*f*) Carbon in carbon dioxid exhaled, $d \times \frac{3}{11}$.
	(*a*) Total amount in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding day.	(*c*) Total amount absorbed from outcoming air.	(*d*) Amount exhaled by subject, $b + c$.	(*e*) Volume exhaled by subject, $d \times 0.5091$.	
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Nov. 10-11	98.04	+12.24	615.83	628.07	319.76	171.29
11-12	26.36	−71.68	716.22	644.54	328.14	175.80
12-13	65.47	+39.11	667.16	706.27	359.56	192.61
Total		−20.33	1,999.21	1,978.88	1,007.46	539.70

The amount exhaled increased gradually from day to day, varying from 628 grams on the first day to 706 grams on the third day. The smallness of the amount is particularly interesting. This is in large part accounted for by the fact that the subject was unusually quiet during this experiment.

Oxygen consumed.—The amounts of oxygen removed from the air current on the different days are given in Table 31.

TABLE 31.—*Daily record of oxygen in ventilating air current and respiratory quotients, metabolism experiment No. 58.*

Date.	Oxygen.						(*g*) Volume of carbon dioxid exhaled.	(*h*) Respiratory quotients, $g \div f$.
	(*a*) Total amount in chamber at end of period.	Gain (+) or loss (−) over preceding day.		(*d*) Amount admitted to chamber.	(*e*) Amount consumed by subject, $d - c$.	(*f*) Volume consumed, $e \times 0.7$		
		(*b*) Volume.	(*c*) Weight, $b \div 0.7$.					
	Liters.	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Nov. 10-11	853.41	−31.96	−45.65	482.85	528.50	369.95	319.76	0.8643
11-12	876.07	+22.66	+32.37	581.35	548.98	384.29	328.14	.8539
12-13	859.56	−16.51	−23.58	565.55	589.13	412.39	359.56	.8719
Total		−25.81	−36.86	1,629.75	1,666.61	1,166.63	1,007.46	.8655

There was an increase of from 528 grams on the first day to 589 grams on the third day. The respiratory quotient, which averaged 0.8655, was fairly constant on the several days. Since the diet was mainly of carbohydrate nature, and the quotient for carbohydrates is 1.0, considerable body material must have been drawn upon to lower the quotient.

Calorimetric measurements.—The data showing the amount of heat eliminated by the subject are summarized in Table 32.

TABLE 32.—*Summary of calorimetric measurements, metabolism experiment No. 58.*

Date.	(*a*) Heat measured in terms C_{20}	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b*×60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total in outgoing air plus excess residual vapor.	(*f*) Heat used in vaporization of water, *e*× 0.592.	(*g*) Total heat determined, *a*+*c*+*d*+*f*.
1903.	*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Nov. 10	1,513.59	−0.04	−2.40	+ 7.72	507.13	300.22	1,819.13
11	1,346.11	− .02	−1.20	+ 9.96	828.78	490.64	1,845.51
12	1,549.27	+ .07	+4.20	+10.16	816.94	483.62	2,047.25
Total, 3 days.	4,408.97	+ .01	+ .60	+27.84	2,152.85	1,274.48	5,711.89

The total amount of heat eliminated was 1,819 calories on the first day, 1,845 calories on the second, and 2,047 calories on the third. There was a much larger quantity of heat measured directly as such (given in terms of the standard calorie at 20° in column *a*) on the first than on the second day, owing to the fact that there was less water vaporized, as previously pointed out, consequently a greater amount of heat radiated from the body. The total amount eliminated on the third day was 200 calories greater than on the second, and as the quantity of water vaporized was practically the same in both cases, the amount of heat radiated directly was 200 calories larger on the third day.

Gains and losses of elements.—The statistics of income and outgo of elements given in the preceding tables, when balanced, show the gains and losses of elements by the body, as given in Table 33.

TABLE 33.—*Gains and losses of elements to the body, metabolism experiment No. 58.*

Date.	Total weight.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Ash.
1903.						
Nov. 10–11:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Total income	1,813.50	6.58	149.82	129.23	1,517.87	10.00
Total outgo	1,587.34	8.19	184.44	104.92	1,281.44	8.35
Gain (+) or loss (−)	+226.16	−1.61	−34.62	+24.31	+236.43	+1.65
Ash of protein lost	− .15					
	+226.01					
Nov. 11–12:						
Total income	1,808.98	6.45	148.05	126.55	1,518.13	9.80
Total outgo	1,921.36	8.67	189.37	140.34	1,574.68	8.30
Gain (+) or loss (−)	−112.38	−2.22	−41.32	−13.79	−56.55	+1.50
Ash of protein lost	− .20					
	−112.58					
Nov. 12–13:						
Total income	1,807.13	6.95	154.75	121.41	1,513.42	10.60
Total outgo	2,018.55	9.74	207.11	144.07	1,648.67	8.96
Gain (+) or loss (−)	−211.42	−2.79	−52.36	−22.66	−135.25	+1.64
Ash of protein lost	− .26					
	−211.68					

Gains and losses of compounds.—The gains or losses of protein, fats, and carbohydrates, as computed from the corresponding gains or losses of the elements, are given in Table 34.

TABLE 34.—*Gains and losses of compounds to the body, metabolism experiment No. 58.*

Date.	Protein.	Fat.	Carbohydrates.	Water.
1903.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 10-11	− 9.66	− 49.24	+17.99	+265.26
11-12	−13.32	− 59.33	+24.47	− 65.91
12-13	−16.74	− 47.86	−16.00	−132.72
Total, 3 days	−39.72	−156.43	+26.46	+ 66.63
Average per day	−13.24	− 52.14	+ 8.82	+ 22.21

The data show clearly that there was a draft upon body fat, as was suggested by the low respiratory quotient when the subject was partaking of a diet markedly carbohydrate in nature. Indeed, there was a loss averaging over 50 grams of body fat per day, while there were gains and losses of carbohydrates which compensated in large measure, the average gain of carbohydrates being about 9 grams per day. There was a marked loss of protein on all three days, increasing from nearly 10 grams on the first day to nearly 17 grams on the third day.

Intake and output of energy.—A summary of the data regarding the intake and output of energy is shown in Table 35.

TABLE 35.—*Income and outgo of energy, metabolism experiment No. 58.*

Date.	Heat of combustion of food and excreta as determined by use of bomb calorimeter.			(*d*) Available energy from food, *d*=*a*−(*b*+*c*).	Heat of combustion of body material gained (+) or lost (−) as calculated by use of factors.*			(*h*) Total energy from body material gained (+) or lost (−), *e*+*f*+*g*.	(*i*) Estimated energy from material oxidized in the body, *d*−*h*.	(*k*) Heat measured by the respiration calorimeter.	Heat measured greater (+) or less (−) than heat estimated.	
	(*a*) Food.	(*b*) Feces.	(*c*) Urine.		(*e*) Protein.	(*f*) Fat.	(*g*) Glycogen.				(*l*) Amount, *k*−*i*.	(*m*) Proportion, *l*÷*k*.
1903.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*P. ct.*
Nov. 10	1,488	67	72	1,349	− 55	− 469	+ 75	− 449	1,798	1,819	+21	+1.2
11	1,469	67	74	1,328	− 75	− 566	+103	− 538	1,866	1,846	−20	−1.1
12	1,543	67	81	1,395	− 95	− 457	− 67	− 619	2,014	2,047	+33	+1.6
Total, 3 days	4,500	201	227	4,072	−225	−1,492	+111	−1,606	5,678	5,712	+34	+0.6
Average per day	1,500	67	76	1,357	− 75	− 497	+ 37	− 535	1,893	1,904	+11	+0.6

* Protein 5.65, fat 9.54, and glycogen 4.19 calories per gram.

The available energy of the food averaged 1,357 calories per day. This was obviously far from sufficient, since there was a draft upon body material sufficient to yield on the average 535 calories per day. The estimated energy from material oxidized in the body ranged from 1,798 calories on the first day to 2,014 calories on the last day, while the heat measured by the respiration chamber ranged from 1,819 calories on the first day to 2,047 calories on the last day. The agreement between the heat measured and the heat estimated is very satisfactory, since the heat measured averaged for the three days but 11 calories more than that estimated, a difference of but 0.6 per cent.

METABOLISM EXPERIMENTS NOS. 60 AND 61.

The subject of these two experiments, B. F. D., was a college student 23 years old and weighing 147 pounds. He had not previously been a subject in these investigations, but he seemed suitable for some experiments that were planned to be carried out with the respiration calorimeter. Accordingly, these two experiments were conducted to measure his metabolism, first during rest and then at work. For the three days comprising experiment No. 60 the subject remained as quiet as possible while conforming to certain requirements in connection with another feature of the experiment explained below. On the fourth day, which comprised experiment No. 61, he performed a considerable amount of muscular work upon the bicycle ergometer. Inasmuch as the subject spent no time previous to the investigation in riding upon the ergometer and accustoming himself to its use, it was hoped that the results of the two experiments would give some information regarding the effect of transition from a condition of relative muscular inactivity to one of considerable activity without previous training.

The most important feature of experiment No. 60 was a study of the effect of a large amount of carbon dioxid in the air of the respiration chamber upon the consumption of oxygen and elimination of carbon dioxid, water, and heat by the subject and upon his general health and comfort. The results of this experiment are therefore of special interest in a consideration of the problems of ventilation, and are utilized in a discussion of this topic in a later section of this bulletin (p. 237).

On the first day of the experiment the subject wore a mask[a] so devised that he would inhale the air from the respiration chamber, while that exhaled was carried out through a flexible tube connecting the mask with the pipe that ordinarily conducts the air out of the chamber. The desire was that the subject should inhale air that was as nearly normal as practicable and was not contaminated by exhalations. Analyses of the air residual in the chamber at the end of the various experimental periods indicated that practically all of the products of respiration were forced into the mask and drawn out in the outgoing air. On the second day the mask was not worn, and there was practically no circulation of air through the system, the intention being to allow the air to become vitiated by the accumulation of the respiratory products. The quantity of carbon dioxid in the air of the chamber on this day increased to relatively enormous proportions. On the third day the conditions of ventilation were the same as in the ordinary experiments.

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[a] See illustration on p. 256.

Programme for experiment No. 60.—At the end of a six-day preliminary feeding period outside the calorimeter the subject entered the respiration chamber on Tuesday evening, January 26, 1904. After accustoming himself to wearing the mask he went to bed with it attached to his face. As it was held in place by means of an elastic band around the head, it did not interfere to any extent with his sleep during the night. Experiment No. 60 began at 7 a. m. the following morning, Wednesday, January 27. The mask was worn practically the entire day, except when the subject was weighing himself. Aside from a slight strain to keep the mask in position no discomfort was noticed by the subject wearing it. As a result of wearing the mask the muscular activity of the subject was considerably more restricted than is commonly the case. The greater part of the day he spent in studying. As no definite programme was prepared for this experiment, record was kept of at least the major movements of the subject on the first day, and an effort was made to have those on the second and third days conform with them, so that in this respect the experiment would be under conditions as nearly comparable as possible.

Programme for experiment No. 61.—It seemed desirable to have the subject follow a definite programme in this experiment; accordingly the following programme was prepared for him:

TABLE 36.—*Daily programme, metabolism experiment No. 61.*

7 a. m.	Take pulse.
7.03 a. m.	(1) Pass urine in jar 4. (2) Collect drip and weigh absorbers. (3) Weigh self, clothes, furniture, etc.
7.30 a. m.	Breakfast.
8.15 a. m.	Begin work.
10 a. m.	Stop work; weigh absorbers.
10.15 a. m.	Begin work.
12.30 p. m.	Stop work.
12.50 p. m.	Remain quiet.
1 p. m.	Pass urine in jar 1; collect drip and weigh absorbers.
1.25 p. m.	Dinner.
2 p. m.	Begin work.
4 p. m.	Stop work; weigh absorbers.
4.15 p. m.	Begin work.
6.15 p. m.	Stop work; change underclothes.
6.20 p. m.	Supper.
7 p. m.	(1) Pass urine in jar 2. (2) Collect drip and weigh absorbers. (3) Weigh self, clothes, furniture, etc.
10 p. m.	Weigh absorbers.
10.45 p. m.	Arrange bed and self for night.
11 p. m.	Pass urine in jar 3; retire.

Food, feces, and urine.—The usual statistics regarding the kind, amount, percentage and total composition, and heat of combustion of the food materials, feces, and urine of these experiments are given in Tables 37 and 38.

TABLE 37.—*Percentage composition and heat of combustion per gram of food materials, feces, and urine, metabolism experiments Nos. 60 and 61.*

Laboratory No.	Kind of material.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion per gram.
	Both experiments.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cals.*
3709	Prepared cereal	8.7	14.1	1.4	73.2	2.6	2.48	41.62	5.87	4.021
3710	do	6.6	11.9	1.0	78.5	2.0	2.09	41.87	5.98	4.094
3711	Butter	13.3	1.4	82.2	......	3.1	.22	63.64	9.86	7.628
3714	Graham crackers	2.3	6.5	13.7	75.4	2.1	1.14	47.21	6.83	4.785
3715	Soda crackers	5.0	8.8	10.5	74.2	1.5	1.55	45.63	6.56	4.613
3716	Beef	63.7	31.2	3.2	......	1.4	4.99	19.11	2.77	2.054
3717	Cereal coffee infusion	99.1	......	......	.9	......	......	.40	.06	.036
	Sugar	......	......	......	100.0	......	......	42.10	6.48	3.960
	Experiment No. 60.									
3713	Milk, skimmed	90.0	3.7	.1	5.4	.8	.60	4.40	.63	.416
3719	Feces	76.8	8.5	2.0	8.5	4.2	1.36	10.61	1.41	1.042
	Urine, first day[a]	94.5	......	......	......	1.5	1.49	1.32	.31	.123
	Urine, second day[a]	94.5	......	......	......	1.5	1.46	1.30	.30	.117
	Urine, third day[a]	94.5	......	......	......	1.5	1.16	1.03	.24	.098
	Experiment No. 61.									
3720	Milk, whole	85.9	3.5	4.4	5.4	.8	.56	7.49	1.13	.821
3721	Feces	75.1	8.3	4.8	7.7	4.1	1.33	12.52	1.75	1.305
	Urine	93.2	......	......	......	1.6	1.82	1.42	.37	.153

[a] Heat of combustion and nitrogen determined from daily samples; other determinations made from composite sample and apportioned among the days according to nitrogen content.

TABLE 38.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiments Nos. 60 and 61.*

Laboratory No.	Kind of material.	(*a*)	(*b*)	Water-free substance.								
				(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	(*h*)	(*i*)	(*k*)	(*l*)
		Total weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Oxygen by difference.	Heat of combustion.
	FOOD.											
	Basal ration.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3715	Soda crackers	150	7.5	13.2	15.7	111.3	2.3	2.33	68.45	9.84	59.58	692
3714	Graham crackers	69	1.6	4.5	9.5	52.0	1.4	.79	32.57	4.71	27.93	330
3709	Prepared cereal	60	5.2	8.5	.8	43.9	1.6	1.49	24.97	3.52	23.22	241
	Sugar	50	......	......	......	50.0	......	......	21.05	3.24	25.71	198
3717	Cereal coffee	150	148.7	......	......	1.3	......	......	.60	.09	.61	5
3711	Butter	20	2.7	.3	16.4	......	.6	.04	12.73	1.97	1.96	153
3710	Prepared cereal	30	2.0	3.6	.3	23.5	.6	.63	12.56	1.79	12.42	123
3716	Beef	100	63.7	31.2	3.2	......	1.4	4.99	19.11	2.77	8.03	205
	Total	629	231.4	61.3	45.9	282.0	7.9	10.27	192.04	27.93	159.46	1,947

Table 38.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiments Nos. 60 and 61*—Continued.

		(a)	(b)	Water-free substance.								
Laboratory No.	Kind of material.	Total weight.	Water.	(c) Protein.	(d) Fat.	(e) Carbohydrates.	(f) Ash.	(g) Nitrogen.	(h) Carbon.	(i) Hydrogen.	(k) Oxygen by difference.	(l) Heat of combustion.
	Food—Continued.											
	Supplemental ration, experiment No. 60.											
	First day:	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3714	Graham crackers....	31	0.7	2.0	4.2	23.4	0.7	0.35	14.64	2.12	12.49	149
	Sugar...............	3	......	......	......	3.0	......	......	1.26	.19	1.55	12
3713	Milk...............	951	855.9	35.2	1.0	51.3	7.6	5.71	41.84	5.99	33.96	396
3717	Cereal coffee..........	72	71.3	......	......	.7	......	......	.29	.04	.37	3
	Total ration, first day..............	1,686	1,159.3	98.5	51.1	360.4	16.2	16.33	250.07	36.27	207.83	2,507
	Second and third days:											
3714	Graham crackers....	31	.7	2.0	4.2	23.4	.7	.35	14.64	2.12	12.49	149
3713	Milk...............	900	810.0	33.3	.9	48.6	7.2	5.40	39.60	5.67	32.13	374
3716	Beef...............	20	12.7	6.2	.6	......	.3	1.00	3.82	.55	1.63	41
	Total ration, second and third days.............	1,580	1,054.8	102.8	51.6	354.0	16.1	17.02	250.10	36.27	205.71	2,511
	Supplemental ration, experiment No. 61.											
	Sugar...............	45	......	......	......	45.0	......	......	18.94	2.92	23.14	178
3720	Milk...............	900	773.1	31.5	39.6	48.6	7.2	5.04	67.41	10.17	37.08	739
3711	Butter...............	93	12.3	1.3	76.5	......	2.9	.21	59.19	9.17	9.23	709
3716	Beef...............	20	12.7	6.2	.6	......	.3	1.00	3.82	.55	1.63	41
	Total ration.......	1,687	1,029.5	100.3	162.6	375.6	18.3	16.52	341.40	50.74	230.54	3,614
	Excreta.											
	Experiment No. 60.											
3719	Total feces for 3 days..	379.2	291.2	32.2	7.6	32.3	15.9	5.16	40.23	5.35	21.36	395
	Average per day...	126.4	97.1	10.7	2.5	10.8	5.3	1.72	13.41	1.78	7.12	132
	Urine, Jan. 27–28.......	1,107.8	1,046.3	......	......	......	16.2	16.45	14.61	3.41	10.84	136
	28–29.......	1,007.2	951.3	......	......	......	14.7	14.74	13.10	3.05	10.30	118
	29–30.......	1,375.2	1,298.9	......	......	......	20.1	15.95	14.17	3.31	22.81	135
	Total urine, 3 days.	3,490.2	3,296.5	......	......	......	51.0	47.14	41.88	9.77	43.95	389
	Experiment No. 61.											
3721	Total feces 1 day.......	1,23.4	92.7	10.2	5.9	9.5	5.1	1.64	15.45	2.16	6.42	161
	Urine, Jan. 30–31......	905.0	843.0	......	......	......	14.6	16.46	12.85	3.35	14.77	138

On the first morning inside the respiration chamber the subject mistook salt for sugar when preparing his food for breakfast. A fresh supply of food was sent in to replace that which he had, allowance being made for what had already been eaten. The total amount of material common to all four days, and tabulated as the basal ration, supplied 61 grams of protein and 1,947 calories of energy. To this was added on the first day Graham crackers, sugar, and skimmed milk, and a small amount of cereal coffee infusion, the supplemental ration being sufficient to increase the protein of the diet to 98 grams and the energy to 2,507 calories. On the second and third days, at the request of the subject for a change in the ration, the cereal coffee and sugar were omitted and a little less milk was given, but a small quantity of the beef was added, the supplemental ration of these days increasing the total protein of the diet to nearly 103 grams and the energy to 2,511 calories. The beef used in these experiments was lean meat, especially prepared, as explained in a previous bulletin.*

In experiment No. 61, the day of work, the basal ration was the same, but the supplemental ration consisted of sugar, whole milk, butter, and beef, the total amount of protein in the diet on this day being 100 grams and that of energy 3,614 calories. Although the quantity of carbohydrate in the diet was but little larger the quantity of fat was over three times as large as in experiment No. 60, the increase being due to the substitution of whole for skimmed milk and the addition of butter to the supplemental ration. Practically all of the increase in the amount of energy in the diet may be ascribed to the fat.

The feces for the three days of experiment No. 60 were separated, dried, and analyzed as usual. Although experiment No. 61 continued but one day an attempt was made to separate the feces pertaining to that day. The lines of separation were fairly clear, but it is somewhat doubtful whether the feces obtained satisfactorily represent the portion that should be ascribed to that experimental day. The total amount thus collected for this experiment was dried and ground separately.

Water eliminated.—The summary of the data regarding the total water of respiration and perspiration is given in Table 39.

TABLE 39.—*Daily record of water of respiration and perspiration, metabolism experiments Nos. 60 and 61.*

Date.	(*a*) Total amount of vapor in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding day.	(*c*) Change in weight of absorbers, gain (+) loss (−).	(*d*) Amount in underclothes.†	(*e*) Total amount gained (+) or lost (−) during day, *b*+*c*+*d*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *e*+*f*†.
1904.							
Experiment No. 60.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 27–28	21.48	− 4.25	....	....	− 4.25	963.79	959.54
28–29	55.69	+34.21	....	....	+ 34.21	237.94	272.15
29–30	37.48	−18.21	+99.0	....	+ 80.79	1,117.90	1,198.69
Total for 3 days	....	+11.75	+99.0	....	+ 110.75	2,319.63	2,430.38
Experiment No. 61.							
Jan. 30–31	47.97	+10.49	1,350.5	146.8	+1,507.79	1,361.66	2,869.45

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*U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 41.

† Including solids of perspiration in experiment No. 61. See explanation, p. 63.

The most striking feature of this table is the marked increase in the water of respiration and perspiration in the work period of experiment No. 61. It is interesting to note that a large proportion of this increase was in the water retained on the heat-absorbing device and in the underclothing. The total amount in the outgoing air current was by no means proportionally increased, as is seen from the figures in column *f*. On the second day, when the carbon dioxid was allowed to accumulate inside the chamber, the amount of water residual in the chamber at the end of the day, as noted in column *g*, was very much larger than is customary, and the total amount in the outgoing air current was a small fraction of the usual amount. The total water of respiration and perspiration for this particular day amounted to 272 grams as against 2,869 grams for the same subject on a work day.

Carbon dioxid eliminated.—The fluctuations in the carbon dioxid eliminated, as shown in Table 40, during this day are especially interesting and are discussed in detail elsewhere (p. 258).

TABLE 40.—*Daily record of carbon dioxid in ventilating air current, metabolism experiments Nos. 60 and 61.*

Date.	Carbon dioxid.					(*f*) Carbon in carbon dioxid exhaled, $d \times \frac{3}{11}$
	(*a*) Total amount in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding day.	(*c*) Total amount absorbed from outcoming air.	(*d*) Amount exhaled by subject, *b*+*c*.	(*e*) Volume exhaled by subject, *d*×0.5091.	
1904.						
Experiment No. 60.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Jan. 27–28	9. 62	+ 7. 75	762. 93	770. 68	392. 35	210. 20
28–29	221. 71	+212. 09	549. 34	761. 43	387. 59	207. 65
29–30	24. 87	−196. 84	1,004. 62	807. 78	411. 23	220. 29
Total for 3 days		+ 23. 00	2,316. 89	2,339. 89	1,191. 17	638. 14
Experiment No. 61.						
Jan. 30–31	29. 50	+ 4. 63	1,595. 00	1,599. 63	814. 36	436. 25

The striking features brought out in this table are, in the first place, the small quantity of carbon dioxid, less than 10 grams, in the chamber at the end of the first day, the large amount, 221 grams, in the chamber at the end of the second day, and the fact that the total amount exhaled by the subject was practically the same on the first and second days, although on the first day the percentage of carbon dioxid in the air was very nearly that of normal air, while on the second day it was approximately 2 per cent. The slight difference between the two days, which is really inappreciable, can be more than accounted for by difference in muscular activity. The increase on the third day is undoubtedly due to the slightly increased muscular activity on the part of the subject, which is manifested by a small increase in the heat elimination and in the oxygen consumption, shown in succeeding tables.

On the work day the amount of carbon dioxid eliminated was very much increased, being almost exactly twice that on the last day of experiment No. 60. This was probably wholly due to the increased muscular activity.

Oxygen consumed.—The data for the oxygen used by the subject in these experiments are given in Table 41.

TABLE 41.—*Daily record of oxygen in ventilating air current and respiratory quotients, metabolism experiments Nos. 60 and 61.*

Date.	Oxygen.						(*g*) Volume of carbon dioxid exhaled.	(*h*) Respiratory quotients, $g \div f$.
	(*a*) Total amount in chamber at end of day.	Gain (+) or loss (−) over preceding day.		(*d*) Amount admitted to chamber.	(*e*) Amount consumed by subject, $d-c$.	(*f*) Volume consumed, $e \times 0.7$.		
		(*b*) Volume.	(*c*) Weight, $b \div 0.7$.					
1904.								
Experiment No. 60.	*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Jan. 27–28	1,056.10	+ 70.69	+100.99	724.40	623.41	436.38	392.35	0.899
28–29	845.10	−211.00	−301.44	325.83	627.27	439.09	387.59	.883
29–30	930.29	+ 85.19	+121.71	757.43	635.72	445.00	411.23	.924
Total for 3 days	....	− 55.12	− 78.74	1,807.66	1,886.40	1,320.47	1,191.17	.902
Experiment No. 61.								
Jan. 30–31	891.29	− 39.00	− 55.72	1,253.37	1,309.09	916.35	814.36	.889

As a result of diminishing the rate of ventilation on the second day, there was a diminution of 211 liters from the total amount of oxygen residual in the chamber on the first day. Perhaps the most interesting fact disclosed by this table is that on the first and second days, with such wide differences in the carbon dioxid content of the respired air, there were practically no differences in the amount of oxygen consumed by the subject. The respiratory quotient, averaging on the rest days 0.902, is what would normally be expected from the consumption of a diet such as was used in this experiment.

The quantity of oxygen consumed on the work day was increased, and in about the same proportion as the carbon dioxid eliminated, there being practically twice as much oxygen consumed on the work day as on the last rest day. The respiratory quotient is somewhat lower than on the rest days, which is wholly in accord with the presence of the increased amount of fat in the diet.

Calorimetric measurements.—The muscular activity on the three days of experiment No. 60 was very nearly uniform and the amount of heat eliminated was much the same each day, as shown in Table 42.

Table 42.—*Summary of calorimetric measurements, metabolism experiments Nos. 60 and 61.*

Date.	(*a*) Heat measured in terms C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b*×60	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total in outgoing air plus excess residual vapor.	(*f*) Heat used in vaporization of water, *e*×0.592.	(*g*) Total heat determined, *a*+*c*+*d*+*f*.
1904.							
Experiment No. 60.	*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Jan. 27	1,645.16	....	....	+ 0.10	959.54	568.05	2,213.31
28	2,037.22	−0.10	−6.00	+ 8.60	272.15	161.11	2,200.93
29	1,605.11	+ .12	+7.20	+ 6.13	1,099.69	651.02	2,269.46
Total for 3 days	5,287.49	+ .02	+1.20	+14.83	2,331.38	1,380.18	6,683.70
Experiment No. 61.							
Jan. 30	3,716.25	− .12	−7.20	+43.67	1,372.15	812.31	4,565.03

The total heat eliminated ranged from 2,200 calories on the second day to 2,269 on the third day, the agreement between the three days being very satisfactory. On the work day the elimination of heat was practically twice that on the rest day.

Gains and losses of elements.—The gains and losses of elements in the rest experiment No. 60 and the work experiment No. 61 are given in Table 43.

Table 43.—*Gains and losses of elements to the body, metabolism experiments Nos. 60 and 61.*

Date.	Total weight.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Ash.[a]
1904.						
Experiment No. 60.						
Jan. 27–28:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Total income	3,009.41	16.33	250.07	244.33	2,482.48	16.20
Total outgo	2,964.42	18.17	238.22	240.50	2,446.06	21.47
Gain (+) or loss (−)	+ 44.99	−1.84	+ 11.85	+ 3.83	+ 36.42	−5.27
Ash of protein lost	− .17	....	....	....	....	....
	+ 44.82	....	....	....	....	....
Jan. 28–29:						
Total income	2,907.27	17.02	250.10	232.63	2,391.42	16.10
Total outgo	2,167.18	16.46	234.16	152.59	1,743.96	20.01
Gain (+) or loss (−)	+740.09	....	+ 15.94	+80.04	+647.46	−3.91
Ash of protein lost	+ .05	+ .56	....	....	....	....
	+740.14	....	....	....	....	....
Jan. 29–30:						
Total income	2,915.72	17.02	250.10	232.63	2,399.87	16.10
Total outgo	3,508.07	17.67	247.87	295.42	2,921.73	25.38
Gain (+) or loss (−)	−592.35	....	+ 2.23	−62.79	−521.86	−9.28
Ash of protein lost	− .06	− .65	....	....	....	....
	−592.41	....	....	....	....	....

[a] Ash considered an element.

TABLE 43.—*Gains and losses of elements to the body, metabolism experiments Nos. 60 and 61*—Continued.

Date.	Total weight.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Ash.
1904.						
Experiment No. 61.						
Jan. 30–31:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Total income	4,830.09	16.52	341.40	371.16	4,082.71	18.30
Total outgo	5,498.27	18.89	464.55	431.30	4,563.90	19.63
Gain (+) or loss (−)	−668.18	−2.37	−123.15	−60.14	−481.19	−1.33
Ash of protein lost	− .22					− .22
	−668.40					−1.55

The subject was nearly in nitrogen equilibrium, there being on the whole a slight loss of nitrogen. There was a gain of carbon, hydrogen, and oxygen, and a marked loss of ash. In experiment No. 61 there was a marked loss of carbon, hydrogen, and oxygen, and a slight loss of nitrogen and ash.

Gains and losses of nutrients.—The gains and losses of compounds as computed from those of elements are shown in Table 44.

TABLE 44.—*Gains and losses of compounds to the body, metabolism experiments Nos. 60 and 61.*

Date.	Protein.	Fat.	Carbohydrates.	Water.
1904.				
Experiment No. 60.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 27–28	−11.04	− 2.73	+ 44.50	+ 19.36
28–29	+ 3.36	−16.03	+ 59.56	+697.16
29–30	− 3.90	+30.19	− 42.25	−567.17
Total for 3 days	−11.58	+11.43	+ 61.81	+149.35
Average per day	− 3.86	+ 3.81	+ 20.60	+ 49.78
Experiment No. 61.				
Jan. 30–31	−14.22	+ 9.85	−277.40	−385.30

In the rest experiment No. 60 the body was as a whole approximately in equilibrium. On the average for the three days there was a loss of 3.86 grams of protein and a gain of 3.81 grams of fat, 20.60 grams of carbohydrates, and 49.78 grams of water. Thus the diet was apparently slightly deficient in protein, but contained sufficient fats and carbohydrates to provide for a slight storage of these nutrients. On the contrary, in experiment No. 61, with severe work, the diet was evidently considerably deficient, for while there was a slight loss of protein and a slight gain of fat, there was a very large loss of carbohydrates and water. It would be interesting to know to what extent this condition was affected by lack of preliminary training by the subject for the performance of this particular kind of muscular exercise, but suitable experiments with him are lacking for the comparison.

Income and outgo of energy.—The computations of the income and outgo of energy in experiments Nos. 60 and 61 are given in Table 45, showing the available energy of the food, the energy from the body material gained or lost, and the estimated energy from material oxidized in the body as compared with the heat measured.

TABLE 45.—*Income and outgo of energy, metabolism experiments Nos. 60 and 61.*

Date.	Heat of combustion of food and excreta as determined by use of bomb calorimeter.			(*d*) Available energy from food, $d=a-(b+c)$.	Heat of combustion of body material gained (+) or lost (−) as calculated by use of factors.*			(*h*) Total energy from body material gained (+) or lost (−), $e+f+g$.	(*i*) Estimated energy from material oxidized in the body, $d-h$.	(*k*) Heat measured by the respiration calorimeter.	Heat measured greater (+) or less (−) than heat estimated.	
	(*a*) Food.	(*b*) Feces.	(*c*) Urine.		(*e*) Protein.	(*f*) Fat.	(*g*) Glycogen.				(*l*) Amount, $k-i$.	(*m*) Proportion, $l \div k$.
1904.												
Experiment No. 60.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*P. ct.*
Jan. 27	2,507	132	136	2,239	−62	− 26	+ 186	+ 98	2,141	2,213	+ 72	+3.3
28	2,511	132	118	2,261	+19	−153	+ 250	+ 116	2,145	2,201	+ 56	+2.5
29	2,511	132	135	2,244	−22	+288	− 177	+ 89	2,155	2,269	+114	+5.0
Total for 3 days	7,529	396	389	6,744	−65	+109	+ 259	+ 303	6,441	6,683	+242	......
Average per day	2,509	132	129	2,248	−21	+ 36	+ 86	+ 101	2,147	2,228	+ 81	+3.6
Experiment No. 61.												
Jan. 30	3,614	161	138	3,315	−80	+ 94	−1,162	−1,148	4,463	4,565	+102	+2.2

* Protein 5.65, fat 9.54, and glycogen 4.19 calories per gram.

The agreement between the estimated and the measured energy is on the whole less satisfactory than in any experiment thus far made. On all four days of the experiments the heat measured by the calorimeter was greater than that estimated to have been oxidized in the body. The average percentage error on the first three days amounted to 3.6 per cent, and on the work day it was 2.2 per cent. The reason for the wide discrepancies that appear in the rest experiment is not clear. Possibly they were due at least in part to the marked change in diet demanded by the subject, in consequence of which the quantities of material in the alimentary tract at the beginning and end of the experiment were not alike, since there was not time enough to secure equilibrium; and in experiment No. 61 the separation of feces for one day may not have been as satisfactory as it appeared.

Before the experiments were completed it had been decided that the temperament of the subject and his dietetic habits were such as to render it inadvisable to use him as a subject for other experiments.

METABOLISM EXPERIMENTS NOS. 62-67.

This series of experiments was made to study (1) the relative effect of fats and carbohydrates as sources of energy for muscular work;

(2) the effect of severe and prolonged work upon metabolism; (3) the metabolism of matter and energy by the subject when operating the bicycle ergometer with no resistance applied by the brake, and (4) the metabolism by the subject when at rest. This was the first time this subject had been used in these investigations, but inasmuch as the season was advancing it was considered best not to make a special experiment to determine his resting metabolism first, as had been customary with preceding subjects, but to begin with the work experiment. Accordingly the four preliminary days were spent by the subject accustoming himself to the use of the bicycle ergometer and to the degree of muscular exercise required in experiments of this character. He entered the respiration chamber at 5 p. m. of April 15, 1904, the fourth preliminary day, and remained there continuously until 7 a. m. of April 27. The period of eleven days in the calorimeter was divided into the six experiments of this series, according to differences in diet and muscular activity.

Experiment No. 62 consisted of the first three days of the period, on which the subject consumed a carbohydrate diet and performed a given amount of work each day on the ergometer. On the next three days, which comprise experiment No. 63, he did the same amount of work while subsisting on a fat diet.

Previous to the beginning of this series of experiments there had been installed in the respiration calorimeter a device[a] by means of which the weights of the subject, his clothing, the bed coverings, the heat-absorbing system, and other articles in the chamber that had hitherto been weighed by the subject inside the calorimeter could now be weighed by the observers on the outside. The use of this device necessitated some changes in the usual programme of the experiments. On the evening of the last preliminary day the subject entered the calorimeter much earlier than had been the custom in previous experiments, and spent the time in drill in the routine of weighing and of other acts that would be required of him. A tentative programme was provided for the subject to follow on the first day, and record was kept of his movements on this day. From these a schedule was prepared, including as many of his movements as possible, but especially the major movements, and the subject was requested to conform to this as closely as practicable on the other two days of experiment No. 62, and on the three days of experiment No. 63, in order that there might be more or less uniformity in the muscular activity on the different days of the experiments that were to be compared. The programme that was followed during these two experiments is given in Table 46.

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[a] Carnegie Inst. Washington Pub. 42, p. 158.

TABLE 46.—*Daily programme, metabolism experiments Nos. 62 and 63.*

7 a. m.	Get up; arrange bed and chair; sit in chair.
7.05 a. m.	Finish weighing; put clothes in chair.
7.05½ a. m.	Put on slippers; if possible, don't touch chair.
7.07 a. m.	Adjust absorbers.
7.11 a. m.	Arrange bed; take temperature; pass urine in jar 4; dress self.
7.20 a. m.	Sit.
7.24 a. m.	Set up table; stand.
7.28 a. m.	Attend to articles at food aperture.
7.32 a. m.	Sit.
7.40 a. m.	Open food aperture; sit.
7.46 a. m.	Eat.
7.54 a. m.	Open food aperture.
8.12 a. m.	Finish eating; put away dishes.
8.16 a. m.	Move about; get out wheel.
8.22 a. m.	Remove clothes.
8.25 a. m.	Set counter and inspect string.
8.26 a. m.	Lower shields; get on wheel.
8.30 a. m.	Begin work.
10 a. m.	Stop work; take temperature.
10.03 a. m.	Open food aperture; put on clothes; sit.
10.15 a. m.	Open food aperture and pass out dishes and bottles; pass out urine jar 4 of day before.
10.26 a. m.	Prepare for riding.
10.30 a. m.	Begin work.
12 m.	Stop work; put on clothes; sit till 1 p. m.
1.01 p. m.	Take temperature.
1.03 p. m.	Pass urine in jar 1.
1.05 p. m.	Open food aperture; eat.
1.50 p. m.	Collect drip; prepare to ride.
2 p. m.	Begin work.
3.30 p. m.	Stop work; put on clothes; open food aperture.
3.35 p. m.	Sit.
4.02 p. m.	Prepare to ride; take temperature.
4.06 p. m.	Begin work.
5.36 p. m.	Stop work; put up wheel.
5.38 p. m.	Change underclothes.
5.44 p. m.	Open food aperture; drink.
5.45 p. m.	Sit.
5.46 p. m.	Rise and put on clothes.
5.52 p. m.	Sit.
6.05 p. m.	Open food aperture; move about; sit.
6.26 p. m.	Get supper; open food aperture.
6.36 p. m.	Eat supper.
7.02 p. m.	Pass urine in jar 2; take temperature.
7.48 p. m.	Move about; sit.
10.02 p. m.	Take temperature.
10.50 p. m.	Collect drip; pass urine in jar 3; prepare for bed.
11 p. m.	Go to bed.

Experiment No. 64 covered only the seventh day of the period. The diet was the same as in No. 63, but the amount of work was over twice that on each of the preceding days. It was not practicable for the subject to follow the same programme as in experiments Nos. 62 and 63. The working periods were different, and they continued into the night, so that the period of sleep was shorter. The schedule of the major movements on this day, as shown by the observer's records, was as follows:

TABLE 47.—*Routine followed by the subject in metabolism experiment No. 64.*

7 a.m.	Rise.
7.05 a. m.	Weigh.
7.16 a. m.	Take temperature.
7.20 a. m.	Dress.
7.30 a. m.	Breakfast.
7.58 a. m.	Prepare to ride; remove clothing
8.01 a. m.	Begin work.
10.01 a. m.	Stop work.
10.02 a. m.	Take temperature.
10.08 a. m.	Dress.
10.24 a. m.	Collect drip; remove clothing.
10.31 a. m.	Start work.
12 m.	Stop work.
12.02 p. m.	Dress.
1.06 p. m.	Take temperature.
1.16 p. m.	Dinner.
1.28 p. m.	Collect drip; remove clothing.
1.30 p. m.	Begin work.
3.30 p. m.	Stop work; dress.
4.04 p. m.	Take temperature.
4.26 p. m.	Prepare to ride; remove clothing.
4.28 p. m.	Start work.
6 p. m.	Stop work.
6.02 p. m.	Dress.
7.04 p. m.	Take temperature.
7.09 p. m.	Prepare to ride; remove clothing.
7.10 p. m.	Begin work.
8.31 p. m.	Stop work.
8.36 p. m.	Dress.
8.37 p. m.	Collect drip.
9.14 p. m.	Prepare to ride; remove clothing.
9.16 p. m.	Start work.
10.16 p. m.	Stop work.
10.18 p. m.	Take temperature.
10.24 p. m.	Dress.
10.56 p. m.	Prepare to ride; remove clothing.
11.01 p. m.	Start work.
11.46 p. m.	Stop work; dress.
1 a. m.	Prepare to ride.
1.03 a. m.	Start work.
1.31 a. m.	Stop work.
1.32 a. m.	Dress.
2.28 a. m.	Prepare to ride; remove clothing.
2.32 a. m.	Begin work.
3.01 a. m.	Stop work.
3.02 a. m.	Collect drip.
3.06 a. m.	Change underclothes.
3.20 a. m.	Sleep.

On the eighth day of the period, which comprises experiment No. 65, the diet was considerably reduced and the subject spent much of the time resting and sleeping after the exhaustive work of the previous day. The observer's record of his activity during the day is shown in Table 48.

TABLE 48.—*Record of movements in experiment No. 65.*

7 a. m.	Rise.
7.04 a. m.	Weigh.
7.14 a. m.	Take temperature.
7.24 a. m.	Breakfast.
7.42 a. m.	Arrange bed.
7.45 a. m.	In bed.
1.04 p. m.	Rise.
1.20 p. m.	Lie down.
4.02 p. m.	Rise.
4.04 p. m.	Take temperature.
4.12 p. m.	Lie down.
5.32 p. m.	Read.
7 p. m.	Rise.
7.10 p. m.	Supper.
7.24 p. m.	Lie down.
8.08 p. m.	Rise.
8.10 p. m.	Lie down.
8.20 p. m.	Lunch.
9.10 p. m.	Rise in bed.
9.12 p. m.	Lie down.
9.28 p. m.	Sit up.
9.40 p. m.	Sit up in bed and read.
9.42 p. m.	Drink.
10 p. m.	Take temperature.
10.04 p. m.	Sit up in bed and read.
11.08 p. m.	Prepare for bed.
11.12 p. m.	Curtain up; in bed.

Experiments Nos. 66 and 67 were designed especially to give information regarding the amount of work incidental to the use of the bicycle ergometer, aside from that necessary to overcome the resistance applied by the electric brake. During the first of these two experiments, i. e., No. 66, which covered the ninth day of the period, the subject performed all the actions necessary to the preparation of himself and the ergometer for work at the usual periods, but did not actually work upon it; that is, he removed his clothing, placed the machine in position for riding, and mounted, then dismounted, put away the ergometer, dressed himself, and spent the remainder of the period as in an ordinary rest experiment. The major movements during this day are shown in the following schedule:

TABLE 49.—*Record of movements in experiment No. 66.*

7 a. m.	Rise.
7.05 a. m.	Weigh.
7.12 a. m.	Take temperature.
7.16 a. m.	Put up table.
7.20 a. m.	Dress.
7.36 a. m.	Breakfast.
8.20 a. m.	Prepare to ride; remove clothing.
8.24 a. m.	Lower and raise shields.
8.26 a. m.	Get on wheel.
8.32 a. m.	Off wheel; dress.
8.34 a. m.	Sit down.
10.28 a. m.	Prepare to ride; remove clothing; get on wheel.
10.32 a. m.	Off wheel; dress.
10.34 a. m.	Sit down.
1.12 p. m.	Dinner.
1.54 p. m.	Collect drip.
2 p. m.	Prepare to ride; remove clothing; get on wheel; off wheel; dress; sit down.
4.00 p. m.	Prepare to ride; remove clothing; take temperature; get on wheel; off wheel; dress; sit down.
5.30 p. m.	Prepare to ride; remove clothing; get on wheel; off wheel; dress.
5.38 p. m.	Sit down.
6.36 p. m.	Read.
7.00 p. m.	Rise.
7.02 p. m.	Take temperature.
7.10 p. m.	Read.
10 p. m.	Take temperature.
10.12 p. m.	Read.
10.50 p. m.	Collect drip.
10.52 p. m.	Prepare for bed.
11 p. m.	Curtain up; in bed.

On the last two days of the period, experiment No. 67, the subject actually rode the bicycle ergometer, but there was no current passing through the electro-magnet and consequently there was no resistance to the revolution of the disk except that due to the bearings, etc., of the machine itself. The schedule of the activities of the subject during each of these two days is shown in Table 50.

TABLE 50.—*Record of movements in experiment No. 67.*

7 a. m.	Rise.
7.05 a. m.	Weigh.
7.12 a. m.	Take temperature.
7.16 a. m.	Dress.
7.20 a. m.	Sit down.
7.44 a. m.	Breakfast.
8.02 a. m.	Read.
8.14 a. m.	Prepare to ride; remove clothing.
8.20 a. m.	Get on wheel.
8.30 a. m.	Begin to ride.
10 a. m.	Stop.
10.02 a. m.	Take temperature.
10.06 a. m.	Dress.
10.24 a. m.	Prepare to ride; dress.
10.26 a. m.	Get on wheel.
10.30 a. m.	Begin to ride.
12 m.	Stop; dress.
12.04 p. m.	Sit down and read.
1.10 p. m.	Dinner.
1.52 p. m.	Prepare to ride; remove clothing; get on wheel.
2 p. m.	Begin to ride.
3.30 p. m.	Stop.
3.32 p. m.	Dress.
3.34 p. m.	Sit down and read.
4.02 p. m.	Prepare to ride; remove clothing.
4.04 p. m.	Take temperature.
4.06 p. m.	Begin to ride.
5.25 p. m.	Stop.
5.28 p. m.	Change underclothes.
5.32 p. m.	Dress.
5.34 p. m.	Sit down and read.
6.14 p. m.	Raise shields.
6.28 p. m.	Supper.
7.14 p. m.	Read.
10.04 p. m.	Take temperature.
10.08 p. m.	Read.
10.54 p. m.	Prepare for bed.
11 p. m.	Curtain up; in bed.

Food, feces, and urine.—The diet in these experiments was varied in accordance with the nature of each of the different experiments so as to furnish the energy required by the body under different circumstances. The usual data regarding the composition and heat of combustion of the food, feces, and urine are given in Table 51.

TABLE 51.—*Percentage composition and heat of combustion per gram of food materials, feces, and urine, metabolism experiments Nos. 62–67.*

Laboratory No.	Kind of material.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion per gram.
	Experiments Nos. 62–67.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cals.*
3769	Prepared cereal	5.0	12.3	0.7	80.1	1.9	2.15	42.84	5.63	4.200
3770	do	7.6	11.0	1.4	77.7	2.3	1.93	41.46	5.32	4.058
3771	Graham crackers	3.2	6.4	13.5	74.7	2.2	1.12	46.62	6.46	4.755
3772	White crackers	6.1	7.6	14.2	70.9	1.2	1.33	46.20	6.19	4.742
3773	Plasmon	9.8	74.5	.1	6.9	8.7	11.92	44.21	5.05	4.829
3774	Milk sugar	5.0	......	......	95.0	......	......	39.99	6.15	3.743
	Cane sugar	......	......	......	100.0	......	......	42.10	6.48	3.960
3775	Shredded wheat	9.4	10.0	1.7	77.2	1.7	1.76	40.94	4.93	4.023
3776	Beef tea	99.0	.5	......	......	.5	.09	.28	.04	.028
	Experiment No. 62.									
3777	Modified milk	82.5	2.9	9.0	4.9	.7	.47	10.09	1.58	1.177
3778	do	81.5	2.9	10.3	4.6	.7	.46	11.18	1.77	1.295
3779	do	79.8	2.9	11.8	4.8	.7	.47	12.38	1.95	1.446
3794	Feces	76.2	7.3	2.3	9.8	4.4	1.16	10.82	1.39	1.150
3799	Urine, first day[a]	90.8	......	......	......	1.3	2.70	2.19	.52	.234
3799	Urine, second day[a]	90.8	......	......	......	1.3	2.76	2.24	.53	.237
3799	Urine, third day[a]	90.8	......	......	......	1.3	2.43	1.97	.47	.200
	Experiments Nos. 63–64.									
3781	Modified cream	63.2	2.3	27.8	6.1	.6	.37	25.40	4.00	3.080
3782	do	72.4	2.8	20.2	4.0	.6	.44	18.24	2.85	2.183
3783	do	75.5	2.6	17.3	3.9	.7	.42	15.77	2.50	1.912
3784	do	82.2	2.9	9.6	4.6	.7	.47	10.50	1.65	1.229
3786	Skim milk	91.2	3.0	.1	4.9	.8	.48	3.94	.59	.367
3787	do	90.6	3.2	.1	5.3	.8	.52	3.85	.57	.400
3795	Feces	73.1	4.8	4.4	11.3	6.4	.76	13.57	2.03	1.581
3800	Urine, first day[a]	95.3	......	......	......	1.3	1.48	1.12	.30	.118
3800	Urine, second day[a]	95.3	......	......	......	1.3	1.05	.79	.21	.080
3800	Urine, third day[a]	95.3	......	......	......	1.3	1.08	.82	.22	.080
3805	Urine, fourth day[a]	94.7	......	......	......	1.1	1.38	1.03	.29	.113

[a] Heat of combustion and nitrogen determined from daily samples; other determinations made from composite sample and apportioned among the days according to nitrogen content.

Table 51.—*Percentage composition and heat of combustion per gram of food materials, feces, and urine, metabolism experiments Nos. 62–67*—Continued.

Laboratory No.	Kind of material.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Nitrogen.	Carbon.	Hydrogen.	Heat of combustion per gram.
	Experiments Nos. 65–67.									
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cals.*
3789	Skim milk	90.3	3.3	0.1	5.5	0.8	0.52	3.94	0.59	0.400
3790	.....do	90.5	3.3	.1	5.4	.7	.52	3.96	.59	.394
3791	.....do	90.0	3.3	.1	5.8	.8	.52	3.93	.59	.394
3796	Feces	74.3	6.3	2.1	7.9	9.4	1.02	9.71	1.32	1.093
3801	Urine, first day[a]	94.2				.9	2.22	1.48	.39	.162
3801	Urine, second day[a]	94.2				.9	2.14	1.43	.37	.151
3801	Urine, third day[a]	94.2				.9	1.71	1.14	.30	.128
3801	Urine, fourth day[a]	94.2				.9	1.22	.81	.21	.091

[a] Heat of combustion and nitrogen determined from daily samples; other determinations made from composite sample and apportioned among the days according to nitrogen content.

The modified milk and modified cream used in these experiments need some explanation. In the earlier experiments difficulty was experienced in making up a palatable diet with a total energy value of 5,000 calories per day, one-half to two-thirds of which was derived from fat. Large amounts of butter were used, but it was found that the subject could not consume enough of this material to supply more than 50 per cent of the total energy required. As a source of energy where fat is required, cream is by far the best material we have thus far used. It is easily digested, well assimilated by most subjects, and when properly handled can be very satisfactorily sampled when not too rich in fat. It is possible to obtain cream with a fat content of 30 per cent or even more, but it has been found impracticable to use such rich cream in these experiments, owing to the difficulty in sampling. The best method is to use a form of modified cream or modified milk.

Whole milk and cream are first subjected to the Babcock test to determine their fat content approximately, and these are then blended in such quantities as to give the desired proportion of fat in the mixture according to the amount of energy to be supplied by the quantity of the modified milk or cream that is to be given to the subject. It has been found more satisfactory to use modified cream with not over 15 to 20 per cent of fat. After the milk and cream have been blended the mixture is again tested by the Babcock method. The proportions of fat as thus determined, however, are used only as tests of the results of the blending of milk and cream, the actual fat content of the mixture finally used being determined by the usual method of analysis.

Preparation of sample for nitrogen determination.—The nitrogen content of milk or cream from the mixed product of a herd of cows is fairly uniform from day to day, at least sufficiently constant for the preliminary calculations where the amount of nitrogen supplied to the subject is to be controlled, as well as the amount of energy. The final determination of the nitrogen of the milk and cream used, however, is made, as previously explained, by the Kjeldahl method. For this purpose we use the sample of milk or cream with which the final Babcock test is made. In making the fat determination three Babcock test bottles are cleaned and dried and at least one of them is weighed. The regulation quantity of modified milk is then delivered into each from the standard milk pipette (i. e., 17.6 cubic centimeters) and the increase in weight of at least one of the bottles is ascertained. The other two bottles are also weighed again if it seems necessary, but it has been found by experience that in general the weights of the different samples of milk as delivered from the same pipette under the same conditions agree very closely, and consequently it is not necessary to weigh all three of the bottles when the precautions in sampling mentioned below have been observed. The fat in the samples in the three bottles is then determined by the usual Babcock method, adding 17.5 cubic centimeters of sulphuric acid with a specific gravity of 1.82. After the proportion of fat in the sample has been read for the final test mentioned above, the fat is withdrawn from the neck of the bottle and the fat-free material used in the Kjeldahl determination. The fat is removed by means of a U tube of small caliber, one end of which is drawn out to a fine point and the other end is passed through a rubber stopper into a small flask. A second tube through another hole in the stopper is connected by a piece of rubber tubing with a suction pump. The pointed end of the U tube is inserted near the top of the fat, and gradually lowered until all is removed as far as the upper surface of the liquid beneath the fat. It is best to introduce a T tube in the rubber tubing between the suction pump and the small exhaustion flask, so that the open arm of the T can be closed with the finger and opened at will, thus carefully regulating the suction. While the fat in the Babcock bottle is still warm it may be drawn quite thoroughly from the neck of the bottle by means of this device. After the fat is removed a few cubic centimeters of ether are poured upon the top of the liquid in the Babcock bottle and after standing for a few seconds removed by the suction. The contents of the Babcock bottle are then emptied into the neck of a Kjeldahl flask, allowed to drain for a few minutes, then 10 cubic centimeters of the sulphuric acid ordinarily used for digestion is put into the Babcock bottle, well shaken, and the acid allowed to drain out into that previously added to the Kjeldahl flask. The sample is then digested and distilled as usual, the actual weight of cream taken being, of course, that originally weighed into the Babcock bottle.

When the fat has been removed from the sample of modified milk in this way the Kjeldahl determination of nitrogen is very greatly facilitated by the prevention of frothing during distillation. It has been shown by repeated tests that even if a few drops of the underlying acid liquid should be drawn over with the ether or with the fat itself by suction, no measurable amount of nitrogen is thus lost.

Precautions in sampling modified milk.—In modified milk or cream with a large fat content, such as were used in these experiments, the cream separates with surprising rapidity and extreme care is necessary to secure an accurate sample. The total quantity of mixed milk prepared for one day is placed in a bottle and thoroughly shaken, and 200 to 300 cubic centimeters immediately poured into a clean 500 cubic centimeter beaker, and this quantity is poured back and forth from one beaker to another immediately before the sample is withdrawn by means of a pipette. By following such precautions no difficulty is experienced in getting the most concordant results in Babcock tests, in fat determinations, and especially in determinations of heats of combustion; but it can not be too strongly emphasized that the milk must be carefully poured back and forth each time a sample is withdrawn, for if the cream is allowed to stand longer than one minute there may be a separation of fat sufficient to render the results of the duplicate tests discordant.

Preparation of modified milk for determination of heat of combustion.—After the sample is thoroughly mixed, as described above, approximately 2 cubic centimeters are withdrawn by means of a pipette and delivered into a weighed capsule, and the capsule, with sample, is again weighed. During the second weighing there will be a slight evaporation of water, but in general the loss in weight is very slight. By noting the time required to weigh the sample and the loss in weight during a similar interval after the first weighing, it is possible to make allowance for loss in weight whenever it seems necessary, but this is rarely done as the error is usually negligible.

In drying the samples of modified milk for the determinations of heat of combustion, if the capsules are placed at once in a drying oven the thin layer of fat on the surface of the milk will greatly retard the evaporation of moisture, and to hasten desiccation the sample must be stirred every five or ten minutes with a short piece of platinum wire that is allowed to remain in the capsule. If time permits, a better procedure is to place the capsules in a vacuum desiccator over night with a vacuum of about 30 millimeters of mercury. Under this treatment a hard scum forms on the surface of the milk and a ring about the capsule at the level of the liquid. If the capsule is subsequently placed in the drying oven and stirred once or twice with the platinum wire the milk dries very rapidly and the fat does not crawl up the sides of the capsule. The sample is dry enough to burn in the bomb calorimeter very soon after it is placed in the drying oven.

When samples of modified milk or cream obtained as above described are prepared and dried in this manner the determinations of the heat of combustion almost invariably agree very closely. A number of tests have shown that if the milk is dried from the start in the water oven, although there is practically no loss of heat of combustion by volatilization of fat or by charring of the desiccated residue while in the oven, there is always danger that some of the fat will crawl up the side of the capsule and may escape complete oxidation. The preliminary treatment in the vacuum desiccator, in our experience, has proven by far the best method for drying the modified milk and cream.

Total amounts of food and excreta.—The total weights of each food material used in the experiments of this series, and the amount of each nutrient and of energy that it contained, are shown in Table 52. The corresponding data for feces and urine are also included in the table.

TABLE 52.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiments Nos. 62–67.*

Laboratory No.	Kind of material.	(a)	(b)	Water-free substance.								
		Total weight.	Water.	(c) Protein.	(d) Fat.	(e) Carbohydrates.	(f) Ash.	(g) Nitrogen.	(h) Carbon.	(i) Hydrogen.	(k) Oxygen by difference.	(l) Heat of combustion.
	FOOD.											
	EXPERIMENT NO. 62.											
	Basal ration.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3770	Prepared cereal......	150	11.4	16.5	2.1	116.5	3.5	2.90	62.19	9.24	60.77	609
3772	Crackers..............	80	4.9	6.1	11.3	56.7	1.0	1.06	36.96	5.50	30.58	379
3771	Graham crackers....	150	4.8	9.6	20.3	112.0	3.3	1.68	69.93	10.23	60.06	713
3769	Malted breakfast food...............	50	2.5	6.1	.4	40.0	1.0	1.08	21.42	3.09	20.91	210
	Total..........	430	23.6	38.3	34.1	325.2	8.8	6.72	190.50	28.06	172.32	1,911
	Supplemental ration.											
	First day:											
3773	Plasmon...........	50	4.9	37.3	......	3.5	4.3	5.96	22.11	3.07	9.66	241
	Cane sugar.........	30	......	......	......	30.0	......	......	12.63	1.94	15.43	119
3774	Milk sugar..........	350	17.5	......	......	332.5	......	......	139.97	21.53	171.00	1,310
3777	Milk (modified)....	889	733.4	25.8	80.0	43.6	6.2	4.18	89.70	14.05	41.47	1,046
	Total ration first day............	1,749	779.4	101.4	114.1	734.8	19.3	16.86	454.91	68.65	409.88	4,627
	Second day:											
3773	Plasmon...........	55	5.4	41.0	......	3.8	4.8	6.56	24.32	3.38	10.54	266
	Cane sugar.........	110	......	......	......	110.0	......	......	46.31	7.13	56.56	436
3774	Milk sugar..........	270	13.5	......	......	256.5	......	......	107.97	16.61	131.92	1,011
3778	Milk (modified)....	775	631.6	22.5	79.8	35.7	5.4	3.57	86.65	13.72	34.06	1,004
	Total ration second day.......	1,640	674.1	101.8	113.9	731.2	19.0	16.85	455.75	68.90	405.40	4,628
	Third day:											
3773	Plasmon...........	58	5.7	43.2	0.1	4.0	5.0	6.91	25.64	3.56	11.19	280
	Cane sugar.........	365	......	......	......	365.0	......	......	153.67	23.65	187.68	1,445
3779	Milk (modified)....	704	561.8	20.4	83.1	33.8	4.9	3.31	87.16	13.73	33.10	1,018
	Total ration third day.....	1,557	591.1	101.0	117.3	728.0	18.7	16.94	456.97	69.00	404.29	4,654

Table 52.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiments Nos. 62–67*—Continued.

Laboratory No.	Kind of material.	(a)	(b)	Water-free substance.								
		Total weight.	Water.	(c) Protein.	(d) Fat.	(e) Carbohydrates.	(f) Ash.	(g) Nitrogen.	(h) Carbon.	(i) Hydrogen.	(k) Oxygen by difference.	(l) Heat of combustion.
	FOOD—Continued.											
	EXPERIMENT No. 63.											
	First day:	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
3775	Shredded wheat	150	14.1	15.0	2.5	115.8	2.6	2.64	61.41	7.40	61.85	603
3772	White crackers	80	4.9	6.1	11.4	56.7	.9	1.06	36.96	4.95	31.23	379
3771	Graham crackers	100	3.2	6.4	13.5	74.7	2.2	1.12	46.62	6.46	40.40	476
	Sugar	30	......	......	......	30.0	......	......	12.63	1.94	15.43	119
3773	Plasmon	70	6.9	52.1	0.1	4.8	6.1	8.34	30.95	3.54	14.17	338
3781	Cream (modified)	950	600.4	21.8	264.1	58.0	5.7	3.52	241.30	38.00	61.08	2,926
	Total	1,380	629.5	101.4	291.6	340.0	17.5	16.68	429.87	62.29	224.16	4,841
	Second day:											
3775	Shredded wheat	67	6.3	6.7	1.1	51.8	1.1	1.18	27.43	3.30	27.69	270
3772	White crackers	80	4.9	6.1	11.4	56.7	.9	1.06	36.96	4.95	31.23	379
3771	Graham crackers	100	3.2	6.4	13.5	74.7	2.2	1.12	46.62	6.46	40.40	476
	Sugar	62	......	......	......	62.0	......	......	26.10	4.02	31.88	246
3773	Plasmon	50	4.9	37.2	......	3.5	4.4	5.96	22.10	2.53	10.11	241
3776	Beef tea	736	728.6	3.7	......	......	3.7	.66	2.06	.29	.69	21
3782	Cream (modified)	1,370	991.9	238.4	276.7	54.8	8.2	6.03	249.89	39.05	74.93	2,991
3786	Skim milk	230	209.8	6.9	.2	11.3	1.8	1.10	9.06	1.36	6.88	84
	Total	2,695	1,949.6	105.4	302.9	314.8	22.3	17.11	420.22	61.96	223.81	4,708
	Third day:											
3772	White crackers	100	6.1	7.6	14.2	70.9	1.2	1.33	462.0	6.19	38.98	474
3771	Graham crackers	100	3.2	6.4	13.5	74.7	2.2	1.12	46.62	6.46	40.40	476
	Sugar	55	......	......	......	55.0	......	......	23.16	3.56	28.28	218
3773	Plasmon	20	2.0	14.9	......	1.4	1.7	2.38	8.84	1.01	4.07	97
3776	Beef tea	365	361.4	1.8	......	......	1.8	.33	1.02	.15	.30	10
3783	Cream (modified)	1,603	1,210.3	41.7	277.3	62.5	11.2	6.73	252.79	40.08	81.90	3,065
3787	Skim milk	924	837.1	29.6	.9	49.0	7.4	4.80	35.57	5.27	33.86	370
	Total	3,167	2,420.1	102.0	305.9	313.5	25.5	16.69	414.20	62.72	227.79	4,710
	EXPERIMENT No. 64.											
3772	White crackers	100	6.1	7.6	14.2	70.9	1.2	1.33	46.20	6.19	38.98	474
3771	Graham crackers	100	3.2	6.4	13.5	74.7	2.2	1.12	46.62	6.46	40.40	476
	Sugar	30	......	......	......	30.0	......	......	12.63	1.94	15.43	119
3773	Plasmon	1.3	.1	1.0	......	.1	.1	.15	.57	.07	.31	6
3784	Cream (modified)	3,513.5	2,888.1	101.9	337.3	161.6	24.6	16.51	368.92	57.97	157.40	4,318
	Total	3,744.8	2,897.5	116.9	365.0	337.3	28.1	19.11	474.94	72.63	252.52	5,393
	EXPERIMENT No. 65.											
3772	White crackers	100	610	7.60	14.20	70.90	1.20	1.33	46.20	6.19	38.98	474
3771	Graham crackers	100	320	6.40	13.50	74.70	2.20	1.12	46.62	6.46	40.40	476
	Sugar	107	......	......	......	107.00	......	......	45.05	6.93	55.02	424
3789	Skim milk	2,487.5	2,246.21	82.09	2.49	136.81	19.90	12.95	98.01	14.68	95.75	995
	Total	2,794.5	2,255.51	96.09	30.19	389.41	23.30	15.40	235.88	34.26	230.15	2,369
	EXPERIMENT No. 66.											
3772	White crackers	100.0	6.10	7.60	14.20	70.90	1.20	1.33	46.20	6.19	38.98	474
3771	Graham crackers	100.0	3.20	6.40	13.50	74.70	2.20	1.12	46.62	6.46	40.40	476
	Sugar	57.7	......	......	......	57.70	......	......	24.29	3.74	29.67	228
3790	Skim milk	2,243.0	2,029.92	74.02	2.24	121.12	15.70	11.66	88.82	13.24	83.66	884
	Total	2,500.7	2,039.22	88.02	29.94	324.42	19.10	14.11	205.93	29.63	192.71	2,062
	EXPERIMENT No. 67.											
	Basal ration.											
3772	White crackers	100	6.10	7.60	14.20	70.90	1.20	1.33	46.20	6.19	38.98	474
3771	Graham crackers	100	3.20	6.40	13.50	74.70	2.20	1.12	46.62	6.46	40.40	476
	Total	200	9.30	14	27.70	145.60	3.40	2.45	92.82	12.65	79.38	950

Table 52.—*Total daily weight, composition, and heat of combustion of food, feces, and urine, metabolism experiments Nos. 62–67*—Continued.

Laboratory No.	Kind of material.	(a)	(b)	Water-free substance.								
		Total weight.	Water.	(c) Protein.	(d) Fat.	(e) Carbohydrates.	(f) Ash.	(g) Nitrogen.	(h) Carbon	(i) Hydrogen.	(k) Oxygen by difference.	(l) Heat of combustion.
	FOOD—Continued.											
	Experiment No. 67—Continued.											
	Supplemental ration.											
	First day:	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
	Sugar	130	......	......	......	130	......	......	54.73	8.42	66.85	515
3791	**Milk**	1,746.6	1,571.94	57.64	1.75	101.30	13.97	9.08	68.64	10.30	72.67	688
	Total ration, first day	2,076.6	1,581.24	71.64	29.45	376.90	17.37	11.53	216.19	31.37	218.90	2,153
	Second day:											
	Sugar	130	......	......	......	130	......	......	54.73	8.42	66.85	515
3791	**Milk**	1,550.8	1,395.72	51.18	1.55	89.94	12.41	8.06	60.95	9.15	64.51	611
	Total ration, second day	1,880.8	1,405.02	65.18	29.25	365.54	15.81	10.51	208.50	30.22	210.74	2,076
	EXCRETA.											
	Experiment No. 62.											
3794	**Total feces for 3 days.**	596.80	454.8	43.6	13.7	58.4	2.63	6.92	64.57	8.30	35.91	686
	Average per day	198.93	151.6	14.5	4.6	19.5	8.77	2.31	21.52	2.76	11.97	229
	Urine, Apr. 16–17	540.2	490.50	......	......	......	6.91	14.57	11.83	2.79	13.60	126
	Urine, Apr. 17–18	544.4	494.30	......	......	......	6.97	15.01	12.19	2.87	13.06	129
	Urine, Apr. 18–19	690.2	626.70	......	......	......	8.83	16.75	13.61	3.21	21.10	138
	Total urine for 3 days	1,774.8	1,611.50	......	......	......	22.71	46.33	37.63	8.87	47.76	393
	Experiment No. 63.											
3795	**Total feces for 3 days.**	398.70	291.45	19.14	17.54	45.05	25.52	3.03	54.10	8.09	16.51	630
	Average per day	132.90	97.15	6.38	5.85	15.01	8.51	1.01	18.03	2.70	5.50	210
	Urine, Apr. 19–20	958.50	913.45	......	......	......	12.46	14.22	10.76	2.84	4.77	113
	Urine, Apr. 20–21	1,845.60	1,758.86	......	......	......	23.99	19.37	14.66	3.88	24.84	148
	Urine, Apr. 21–22	1,843.70	1,757.04	......	......	......	23.97	19.85	15.02	3.97	23.85	147
	Total urine for 3 days	4,647.80	4,429.35	......	......	......	60.42	53.44	40.44	10.69	53.46	408
	Experiment No. 64.											
3795	**Total feces for 1 day**	132.90	97.15	6.38	5.85	15.01	8.51	1.01	18.03	2.70	5.50	210
	Urine, Apr. 22–23	1,136.10	1,075.55	......	......	......	12.72	15.68	11.70	3.29	17.16	128
	Experiment No. 65.											
3796	**Total feces for 1 day**	83.67	62.17	5.27	1.76	6.61	7.86	.85	8.13	1.10	3.56	92
	Urine, Apr. 23–24	1,083.60	1,020.64	......	......	......	10.19	24.02	16	4.17	8.58	176
	Experiment No. 66.											
3796	**Total feces for 1 day**	83.67	62.17	5.27	1.76	6.61	7.86	.85	8.13	1.10	3.56	92
	Urine, Apr. 24–25	1,041.70	981.18	......	......	......	9.79	22.31	14.87	3.87	9.68	157
	Experiment No. 67.											
3796	**Total feces for 2 days.**	167.34	124.34	10.54	3.52	13.22	15.73	1.71	16.25	2.21	7.12	183
	Average per day	83.67	62.17	5.27	1.76	6.61	7.86	.85	8.13	1.10	3.56	92
	Urine, Apr. 25–26	1,076.30	1,013.77	......	......	......	10.12	18.45	12.29	3.20	18.47	138
	Urine, Apr. 26–27	1,344.40	1,266.29	......	......	......	12.64	16.42	10.94	2.85	35.26	122
	Total urine for 2 days	2,420.70	2,280.06	......	......	......	22.76	34.87	23.23	6.05	53.73	260

The diet used in these experiments was really quite restricted in variety, and especially for one that extended over eleven days. The basal portion of the ration consisted of two kinds of cereal breakfast foods and white and graham crackers. The total quantity of these materials used in experiment No. 62 contained 38 grams of protein and 1,911 calories of energy. This was supplemented by cane sugar, milk sugar, modified milk, and plasmon, a proteid preparation from milk. The quantities of these materials used varied somewhat on the different days, but in each case they were regulated so as to maintain as nearly as possible a total of 101 grams of protein and 4,625 calories of energy in the diet and to have the larger proportion of the energy supplied by carbohydrates. On each of the three days of this experiment about 66 per cent of the total energy was from such source.

In experiment No. 63 there were slight variations in the ration on each of the three days, which were, for the most part, required to satisfy the appetite of the subject, consequently the diet could not be separated into a uniform basal ration and a more or less variable supplemental ration, as in previous experiments. The total quantity of protein in the diet ranged from 101 to 105 grams per day, and the total quantity of energy from 4,708 to 4,841 calories. About 67 per cent of the total energy of the diet in this experiment was derived from fat.

In experiment No. 64, when excessive muscular work was performed, the diet consisted simply of white and graham crackers; sugar, a small amount of plasmon, and a large amount of modified cream, the total ration being considerably increased over that in experiment No. 63, and containing almost 117 grams of protein and 5,400 calories of energy, about 60 per cent of the energy being derived from fat.

In experiment No. 65, when the subject slept a good portion of the day, the ration was considerably reduced. The quantity of white and graham crackers was the same as in the preceding experiment, and the quantity of sugar was over three times as large, but in place of the modified cream skimmed milk was used, so that the total protein of the diet was less than 100 grams, and the total energy less than 2,400 calories.

There were likewise slight variations in the diets for experiments Nos. 66 and 67. During the last experiment a basal ration of white and graham crackers was supplemented by sugar and skim milk, the total ration for each of the two days supplying approximately 2,100 calories of energy.

Separation of the feces was made for experiments Nos. 62 and 63, and also for the one day of experiment No. 64, but the total amount of feces for the four days of experiments Nos. 65, 66, and 67 was collected and analyzed and the constituents apportioned among the four days.

Water eliminated.—In Table 53 the total water of respiration and perspiration is shown.

TABLE 53.—*Daily record of water of respiration and perspiration, metabolism experiments Nos. 62–67.*

Date.	(*a*) Total amount of vapor in chamber at end of day.	(*b*) Gain (+) or loss (−) over preceding day.	(*c*) Change in weight of absorbers, gain (+) or loss (−).	(*d*) Amount in underclothes.*	(*e*) Total amount gained (+) or lost (−) during the day, *b*+*c*+*d*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration,* *e*+*f*.
1904.							
Experiment No. 62.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 16–17	55.59	+ 6.33	+2,009.5	112.3	+2,129.13	1,287.72	3,415.85
17–18	50.73	− 4.86	+1,565.1	78.9	+1,639.14	1,294.81	2,933.95
18–19	57.29	+ 6.56	+2,289.5	98.8	+2,394.86	1,178.33	3,573.19
Total for 3 days	....	+ 8.03	+5,864.1	290.0	+6,162.13	3,760.86	9,922.99
Experiment No. 63.							
Apr. 19–20	61.00	+ 3.71	+2,472.1	152.1	+2,627.91	1,324.78	3,952.69
20–21	62.65	+ 1.65	+1,979.9	182.7	+2,164.25	1,314.78	3,479.03
21–22	52.44	−10.21	+2,167.4	178.0	+2,335.19	1,318.77	3,653.96
Total for 3 days	....	− 4.85	+6,619.4	512.8	+7,127.35	3,958.33	11,085.68
Experiment No. 64.							
Apr. 22–23	60.39	+ 7.95	+4,359.6	92.2	+4,459.75	1,479.92	5,939.67
Experiment No. 65.							
Apr. 23–24	51.66	− 8.73	− 159.0	....	− 167.73	1,240.19	1,072.46
Experiment No. 66.							
Apr. 24–25	46.14	− 5.52	− 176.8	....	− 182.32	1,066.15	883.83
Experiment No. 67.							
Apr. 25–26	45.48	− .66	− 116.0	....	− 116.66	958.94	842.28
26–27	44.64	− .84	− 35.0	....	− 35.84	913.60	877.76
Total for 2 days	....	− 1.50	− 151.0	....	− 152.50	1,872.54	1,720.04

* Including solids of perspiration in experiments Nos. 62–64. See explanation, p. 63.

During the work experiments there were very great changes in the weight of the heat-absorbing system, as shown in column *c*, and the underclothes absorbed considerable quantities of water. The total amount in the outgoing air remained relatively constant, although varying somewhat more per day in experiment No. 63 than in No. 62. Even in the excessive work day of experiment No. 64 the total amount in the outgoing air was but slightly increased above that in the previous experiment. There was a diminution in the amount leaving the air on the successive days of the rest experiments, ranging from 1,240 grams in experiment No. 65 to 913 grams on the last day of experiment No. 67. In the last column marked variations of the total water of respiration and perspiration are observed.

Carbon dioxid eliminated.—The results regarding the elimination of carbon dioxid in the series of experiments Nos. 62–67 are given in Table 54.

TABLE 54.—*Daily record of carbon dioxid in ventilating air current, metabolism experiments Nos. 62–67.*

Date.	Carbon dioxid.					(f)
	(a) Total amount in chamber at end of day.	(b) Gain (+) or loss (−) over preceding day.	(c) Total amount absorbed from outcoming air.	(d) Amount exhaled by subject, b+c.	(e) Volume exhaled by subject, $d\times0.5091$.	Carbon in carbon dioxid exhaled, $d\times\frac{3}{11}$.
1904.						
Experiment No. 62.						
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Apr. 16–17	28.64	−0.55	1,696.49	1,695.94	863.40	462.52
17–18	31.86	+3.22	1,721.20	1,724.42	877.89	470.32
18–19	34.53	+2.67	1,699.35	1,702.02	866.50	464.20
Total for 3 days		+5.34	5,117.04	5,122.38	2,607.79	1,397.04
Experiment No. 63.						
Apr. 19–20	30.17	−4.36	1,606.05	1,601.69	815.42	436.81
20–21	32.94	+2.77	1,578.10	1,580.87	804.82	431.15
21–22	30.95	−1.99	1,580.42	1,578.43	803.58	430.48
Total for 3 days		−3.58	4,764.57	4,760.99	2,423.82	1,298.44
Experiment No. 64.						
Apr. 22–23		+2.69	2,341.32	2,344.01	1,193.33	639.27
Experiment No. 65.						
Apr. 23–24	29.48	−4.16	819.20	815.04	414.94	222.28
Experiment No. 66.						
Apr. 24–25	36.93	+7.45	832.29	839.74	427.52	229.03
Experiment No. 67.						
Apr. 25–26	36.77	− .16	951.71	951.55	484.44	259.52
26–27	43.73	+6.96	945.12	952.08	484.71	259.64
Total for 2 days		+6.80	1,896.83	1,903.63	969.15	519.16

The amount of carbon dioxid exhaled was fairly uniform for the three days of experiment No. 62, and again for the three days of experiment No. 63; but the average amount per day was somewhat less in the latter, with the fat diet, than in the former with the carbohydrate diet. On the excessive work day the amount rose to 2,344 grams. The day following hard work, in which the subject spent most of the time in sleep, the amount exhaled was 815 grams, about one-third that of the severe work day. In experiment No. 66 there was a slight increase over that in No. 65, since the subject, though at rest, was somewhat more active and did not sleep quite so much; and in experiment No. 67, when light exercise was taken on the bicycle ergometer, the amount of carbon dioxid exhaled per day was appreciably larger, practically 950 grams on both days.

Oxygen.—The quantities of oxygen consumed by the subject and the respiratory quotients are given in Table 55.

TABLE 55.—*Daily record of oxygen in ventilating air current and respiratory quotients, metabolism experiments Nos. 62–67.*

Date.	(a) Total amount in chamber at end of day.	Oxygen.					(g) Volume of carbon dioxid exhaled.	(h) Respiratory quotients, g+f.
		Gain (+) or loss (−) over preceding day.		(d) Amount admitted to chamber.	(e) Amount consumed by subject, d−c.	(f) Volume consumed, e × 0.7.		
		(b) Volume.	(c) Weight, b+0.7.					
1904.								
Experiment No. 62.	*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Apr. 16–17	876.75	+ 29.99	+ 42.84	1,414.51	1,371.67	960.18	863.40	0.898
17–18	805.10	− 71.65	−102.36	1,285.31	1,387.67	971.38	877.89	.905
18–19	776.52	− 28.58	− 40.83	1,358.43	1,399.26	979.49	866.50	.884
Total for 3 days	....	− 70.24	−100.35	4,058.25	4,158.60	2,911.05	2,607.79	....
Experiment No. 63.								
Apr. 19–20	754.62	− 21.90	− 31.29	1,377.60	1,408.89	986.22	815.42	.727
20–21	865.16	+110.54	+157.92	1,611.92	1,454.00	1,017.81	804.82	.891
21–22	1,033.12	+167.96	+239.95	1,694.29	1,454.34	1,018.05	803.58	.789
Total for 3 days	....	+256.60	+366.58	4,683.81	4,317.23	3,022.08	2,423.82	....
Experiment No. 64.								
Apr. 22–23	1,028.45	− 4.67	− 6.68	2,098.97	2,105.65	1,473.96	1,193.33	.809
Experiment No. 65.								
Apr. 23–24	979.78	− 48.67	− 69.52	659.64	729.16	510.39	414.94	.813
Experiment No. 66.								
Apr. 24–25	882.50	− 97.28	−138.97	568.03	707.00	494.91	427.52	.864
Experiment No. 67.								
Apr. 25–26	865.82	− 16.68	− 23.84	767.19	791.03	553.72	484.44	.875
26–27	913.56	+ 47.74	+ 68.20	866.07	797.87	558.52	484.71	.868
Total for 2 days	....	+ 31.06	+ 44.36	1,633.26	1,588.90	1,112.24	969.15	.872

In experiment No. 62 the amount of oxygen consumed by the subject ranged from 1,371 grams on the first day to 1,399 grams on the third. In experiment No. 63 the consumption of oxygen was slightly larger, ranging from 1,408 grams on the first day to 1,454 grams on the third. The respiratory quotient during the first experiment, with a carbohydrate diet, was not far from 0.9, while in experiment No. 63, by reason of the large proportion of fat in the diet, it fell to 0.8. The consumption of oxygen in experiment No. 64 increased practically 50 per cent over that in experiment No. 63, the respiratory quotient remaining practically the same. In experiment No. 65 the amount of oxygen consumed fell off greatly. There was a still further diminution in experiment No. 66, and an increase on the two days of experiment No. 67. The respiratory quotient in experiment No. 65 remained nearly the same as that of experiment No. 64, but on the three following days of this series it rose to practically 0.87.

Calorimetric measurements.—The amount of heat eliminated by the subject during this series of experiments is shown in Table 56.

TABLE 56.—*Summary of calorimetric measurements, metabolism experiments Nos. 62–67*

Date.	(*a*) Heat measured in terms C_{20}.	(*b*) Change in temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b*×60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total in outgoing air plus excess residual vapor.	(*f*) Heat used in vaporization of water, *e*×0.592.	(*g*) Total heat determined, *a*+*c*+*d*+*f*.
1904.							
Experiment No. 62.	*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories*	*Calories.*
Apr. 16	3,987.47	−0.02	− 1.20	+ 49.95	1,294.05	766.08	4,802.30
17	4,000.39	+ .01	+ .60	+ 45.12	1,289.95	763.65	4,809.76
18	4,110.15	+ .07	+ 4.20	+ 36.51	1,184.89	701.45	4,852.31
Total for 3 days	12,098.01	+ .06	+ 3.60	+131.58	3,768.89	2,231.18	14,464.37
Experiment No. 63.							
Apr. 19	4,121.06	− .07	− 4.20	+ 43.41	1,328.49	786.47	4,946.74
20	4,099.02	+ .25	+15.00	+ 7.43	1,316.43	779.32	4,900.77
21	4,043.02	− .24	−14.40	+ 19.29	1,308.56	774.67	4,822.58
Total for 3 days	12,263.10	− .06	− 3.60	+ 70.13	3,953.48	2,340.46	14,670.09
Experiment No. 64.							
Apr. 22	6,147.95	+ .10	+ 6.00	+101.93	1,487.87	880.82	7,136.70
Experiment No. 65.							
Apr. 23	1,682.21	− .09	− 5.40	+ 47.44	1,231.46	729.02	2,453.27
Experiment No. 66.							
Apr. 24	1,804.84	− .05	− 3.00	+ 40.81	1,060.63	627.89	2,470.54
Experiment No. 67.							
Apr. 25	2,049.23	+ .06	+ 3.60	+ 34.83	958.28	567.30	2,654.96
26	2,153.22	− .04	− 2.40	+ 30.76	912.76	540.35	2,721.93
Total for 2 days	4,202.45	+ .02	+ 1.20	+ 65.59	1,871.04	1,107.65	5,376.89

The total heat determined per day increased in experiment No. 62 from 4,802 calories on the first day to 4,852 calories on the third; whereas in experiment No. 63 it decreased from 4,946 calories on the first day to 4,822 calories on the third. The total elimination was somewhat larger in the second three days than in the first. In experiment No. 64, with excessive work, the heat elimination of course increased markedly. On the two following days, experiments Nos. 65 and 66, the daily elimination was a little below 2,500 calories, evidently the resting metabolism of this subject. The light muscular exercise of experiment No. 67 increased the heat output to about 2,700 calories per day.

Gains and losses of elements.—The gains and losses of elements as found from the detailed data of the experiments are summarized in Table 57.

Table 57.—*Gains and losses of elements to the body, metabolism experiments Nos. 62–67.*

Date.	Total weight.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Ash.[a]
1904.						
Experiment No. 62.						
Apr. 16–17:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Total income	5,918.57	16.86	454.91	468.95	4,958.55	19.30
Total outgo	5,850.92	16.88	495.87	459.63	4,862.86	15.68
Gain (+) or loss (−)	+ 67.65	− .02	− 40.96	+ 9.32	+ 95.69	+ 3.62
Ash of protein lost						
Apr. 17–18:						
Total income	5,906.77	16.85	455.75	466.50	4,948.67	19.00
Total outgo	5,401.70	17.32	504.03	406.21	4,458.40	15.74
Gain (+) or loss (−)	+ 505.07	− .47	− 48.28	+ 60.29	+ 490.27	+ 3.26
Ash of protein lost	− .04					− .04
	+ 505.03					+ 3.22
Apr. 18–19:						
Total income	5,856.26	16.94	456.97	459.65	4,904.00	18.70
Total outgo	6,164.34	19.06	499.33	492.90	5,135.45	17.60
Gain (+) or loss (−)	− 308.08	− 2.12	− 42.36	− 33.25	− 231.45	+ 1.10
Ash of protein lost	− .19					− .19
	− 308.27					+ .91
Experiment No. 63.						
Apr. 19–20:						
Total income	5,267.49	16.68	420.87	410.09	4,393.35	17.50
Total outgo	6,645.78	15.23	465.60	560.94	5,583.04	20.97
Gain (+) or loss (−)	−1,378.29	− 1.45	− 35.73	− 150.85	−1,189.69	− 3.47
Ash of protein gained	+ .13					+ .13
	−1,378.16					− 3.34
Apr. 20–21:						
Total income	6,349.70	17.11	420.22	526.38	5,363.69	22.30
Total outgo	7,038.40	20.38	463.84	603.57	5,918.11	32.50
Gain (+) or loss (−)	− 688.70	− 3.27	− 43.62	− 77.19	− 554.42	−10.20
Ash of protein lost	− .30					− .30
	− 689.00					−10.50
Apr. 21–22:						
Total income	6,353.14	16.69	414.20	527.32	5,369.43	25.50
Total outgo	7,208.99	20.86	463.53	623.03	6,069.09	32.48
Gain (+) or loss (−)	− 855.85	− 4.17	− 49.33	− 95.71	− 699.66	− 6.98
Ash of protein lost	− .38					− .38
	− 856.23					− 7.26
Experiment No. 64.						
Apr. 22–23:						
Total income	9,682.45	19.11	474.94	825.66	8,334.64	28.10
Total outgo	9,552.68	16.69	669.00	801.86	8,043.90	21.23
Gain (+) or loss (−)	+ 129.77	+ 2.42	−194.06	+ 23.80	+ 290.74	+ 6.87
Ash of protein gained	+ .22					+ .22
	+ 129.99					+ 7.09
Experiment No. 65.						
Apr. 23–24:						
Total income	3,523.66	15.40	235.88	286.65	2,962.43	23.30
Total outgo	3,054.77	24.87	246.41	246.45	2,518.99	18.05
Gain (+) or loss (−)	+ 468.89	− 9.47	− 10.53	+ 40.20	+ 443.44	+ 5.25
Ash of protein lost	− .87					− .87
	+ 468.02					+ 4.38

[a] Ash here considered an element.

TABLE 57.—*Gains and losses of elements to the body, metabolism experiments Nos. 62–67*—Continued.

Date.	Total weight.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Ash.
1904						
Experiment No. 66.						
Apr. 24-25:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Total income	3,207.70	14.11	205.93	257.82	2,710.74	19.10
Total outgo	2,848.94	23.16	252.03	220.62	2,335.48	17.65
Gain (+) or loss (−)	+ 358.76	− 9.05	− 46.10	+ 37.20	+ 375.26	+ 1.45
Ash of protein lost	− .83	....	....	....	....	− .83
	+ 357.93	....	....	....	....	+ .62
Experiment No. 67.						
Apr. 25-26:						
Total income	2,867.63	11.53	216.19	208.31	2,414.23	17.37
Total outgo	2,953.80	19.30	279.94	218.95	2,417.63	17.98
Gain (+) or loss (−)	− 86.17	− 7.77	− 63.75	− 10.64	− 3.40	− .61
Ash of protein lost	− .71	....	....	....	....	− .71
	− 86.88	....	....	....	....	− 1.32
Apr. 26-27:						
Total income	2,678.67	10.51	208.50	187.44	2,256.41	15.81
Total outgo	3,257.91	17.27	278.71	250.83	2,690.60	20.50
Gain (+) or loss (−)	− 579.24	− 6.76	− 70.21	− 63.39	− 434.19	− 4.69
Ash of protein lost	− .62	....	....	....	....	− .62
	− 579.86	....	....	....	....	− 5.31

In experiment No. 62, on the carbohydrate diet, there was for the three days as a whole a loss of nitrogen by the body, which increased on the three successive days, a loss of carbon much the same for each day, a slight gain of hydrogen, and a marked gain in oxygen. In experiment No. 63, on the fat diet, the loss of nitrogen increased materially, the loss of carbon remained substantially the same, and there was in this case a loss of hydrogen and a noticeable loss in oxygen; also, while there was a gain of ash on all three days in experiment No. 62, there was a loss of ash on all days of experiment No. 63. On the heavy work day in experiment No. 64, there was a gain of nitrogen, a very marked loss of carbon, and gains of hydrogen, oxygen, and ash. The rest day following severe work, experiment No. 65, was marked by a much greater loss of nitrogen, a slight loss of carbon, and marked gains of hydrogen, oxygen, and ash. The same may be said for experiment No. 66. In experiment No. 67 the large loss of nitrogen continued on both days, and there was a loss of carbon, hydrogen, oxygen, and ash, which was greater on the second day than on the first.

Gains and losses of compounds.—The gains or losses of compounds computed from those of elements are given in Table 58.

TABLE 58.—*Gains and losses of compounds to the body, metabolism experiments Nos. 62-67.*

Date.	Protein.	Fat.	Carbohydrates.	Water.
1904.				
Experiment No. 62.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 16-17	– 0.12	– 26.65	– 46.37	+ 137.17
17-18	–2.82	– 13.31	– 82.39	+ 600.29
18-19	–12.72	– 34.65	– 20.92	– 241.08
Total for 3 days	–15.66	– 74.61	–149.68	+ 496.38
Average per day	– 5.22	– 24.87	– 49.89	+ 165.46
Experiment No. 63.				
Apr. 19-20	+ 8.70	– 13.35	– 68.28	–1,301.75
20-21	–19.62	– 63.38	+ 33.57	– 629.37
21-22	–25.02	– 63.35	+ 27.05	– 787.93
Total for 3 days	–35.94	–140.08	– 7.66	–2,719.05
Average per day	–11.98	– 46.69	–2.55	– 906.35
Experiment No. 64.				
Apr. 22-23	+14.52	–131.26	–229.15	+ 469.01
Experiment No. 65.				
Apr. 23-24	–56.82	–128.39	+264.05	+ 383.93
Experiment No. 66.				
Apr. 24-25	–54.30	– 75.43	+ 90.18	+ 396.03
Experiment No 67.				
Apr. 25-26	–46.62	– 80.06	+ 49.13	– 8.72
26-27	–40.56	– 67.91	+ 6.41	– 473.11
Total for 2 days	–87.18	–147.97	+ 55.54	– 481.83
Average per day	–43.59	– 73.99	+ 27.77	– 240.92

In experiment No. 62 there was on the average for the three days a loss of protein, fat, and carbohydrates, and a gain of water. In experiment No. 63 the average loss in protein and fat was somewhat larger, but that of carbohydrates was very small; there was, however, a large loss of water. In experiment No. 64, since the diet was insufficient to furnish the energy required for the excessive work, there was, as would be expected, a marked loss in both fat and carbohydrates on this day, but there was also a considerable gain of protein and a decided gain of water. On the days following the excessive work there was a very noticeable loss of protein, which persisted until the end of the series, and in experiment No. 65 there was a marked loss of fat and a decided gain in carbohydrates, with a considerable gain of water. In experiment No. 66 there was a still greater loss of fat and gain in carbohydrates; and in experiment No. 67, on the first day the loss of fat and the gain of carbohydrates persisted, while in the last day there was still a loss of fat, but the body had practically reached equilibrium regarding carbohydrates.

Income and outgo of energy.—The estimated amount of energy from material oxidized in the body, as compared with the heat measured by the respiration calorimeter, is shown in Table 59.

TABLE 59.—*Income and outgo of energy, metabolism experiments Nos. 62 to 67.*

Date.	Heat of combustion of food and excreta as determined by use of bomb calorimeter.			(*d*) Available energy from food, $d=a-(b+c)$.	Heat of combustion of body materials gained (+) or lost (−) as calculated by use of factors.*			(*h*) Total energy from body material gained (+) or lost (−), $e+f+g$.	(*i*) Estimated energy from material oxidized in the body, $d-h$.	(*k*) Heat measured by the respiration calorimeter.	Heat measured greater (+) or less (−) than heat estimated.	
	(*a*) Food.	(*b*) Feces.	(*c*) Urine.		(*e*) Protein.	(*f*) Fat.	(*g*) Glycogen.				(*l*) Amount, $k-i$.	(*m*) Proportion, $l \div k$.
Experiment No. 62.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*P. ct.*
Apr. 16–17	4,627	229	126	4,272	− 1	− 254	− 194	− 449	4,721	4,802	+ 81	+1.7
17–18	4,628	229	129	4,270	− 16	− 127	− 345	− 488	4,758	4,810	+ 52	+1.1
18–19	4,654	229	138	4,287	− 72	− 331	− 88	− 491	4,778	4,852	+ 74	+1.5
Total for 3 days	13,909	687	393	12,829	− 89	− 712	− 627	−1,428	14,257	14,464	+207	......
Average per day	4,636	229	131	4,276	− 30	− 237	− 209	− 476	4,752	4,821	+ 69	+1.4
Experiment No. 63.												
Apr. 19–20	4,841	210	113	4,518	+ 49	− 127	− 286	− 364	4,882	4,947	+ 65	+1.3
20–21	4,708	210	148	4,350	−111	− 605	+ 141	− 575	4,925	4,901	− 24	−0.5
21–22	4,710	210	147	4,353	−141	− 604	+ 113	− 632	4,985	4,823	−162	−3.4
Total for 3 days	14,259	630	408	13,221	−203	−1,336	− 32	−1,571	14,792	14,671	−121	......
Average per day	4,753	210	136	4,407	− 68	− 445	− 11	− 524	4,931	4,890	− 41	−0.8
Experiment No. 64.												
Apr. 22–23	5,393	210	128	5,055	+ 82	−1,252	− 960	−2,130	7,185	7,137	− 48	−0.7
Experiment No. 65.												
Apr. 23–24	2,369	92	176	2,101	−321	−1,225	+1,106	− 440	2,541	2,453	− 88	−3.6
Experiment No. 66.												
Apr. 24–25	2,062	92	157	1,813	−307	− 720	+ 378	− 649	2,462	2,471	+ 9	+0.4
Experiment No. 67.												
Apr. 25–26	2,153	92	138	1,923	−263	− 763	+ 206	− 820	2,743	2,655	− 88	−3.3
26–27	2,076	92	122	1,862	−229	− 648	+ 27	− 850	2,712	2,722	+ 10	+0.4
Total for 3 days	4,229	184	260	3,785	−492	−1,411	+ 233	−1,670	5,455	5,377	− 78	−2.9
Average per day	2,115	92	130	1,893	−246	− 706	+ 117	− 835	2,728	2,689	− 39	−1.5
Average for 11 days	3,838	172	138	1,094	−121	− 605	+ 9	− 717	4,245	4,234	−119	−0.5

* Protein 5.65, fat 9.54, glycogen 4.19 calories per gram.

In experiment No. 62 there was on the whole a slightly larger amount, and in No. 63 a slightly smaller amount, of energy measured by the calorimeter than was estimated to be oxidized in the body. In the excessive work experiment, No. 64, the agreement was also satisfactory, there being a discrepancy of but 0.7 per cent. In experiment No. 65 the agreement is not as close as could be desired, the energy as measured by the calorimeter being 3.6 per cent less than that estimated to be oxidized by the body. The following day the agreement was close, but another decided difference was noted on the first day of experiment No. 67, while on the last day the agreement was very close. The average error for the eleven days of the whole series is but 0.5 per cent.

GENERAL SUMMARY AND DISCUSSION.

Some of the particular features of the results of the experiments reported in the present bulletin have been pointed out on the preceding pages in the accounts of the several experiments; for more general discussion, however, the results of the different experiments have been summarized in various ways in connection with the topics considered on the following pages. In a number of instances these are largely a continuation of the discussion of similar topics in previous bulletins of this Office, and in some instances the data obtained in previous investigations have also been considered in the present discussion. For the most part, however, the discussion is confined principally to the results obtained in the present investigations. In general, no attempt has been made to compare the results obtained in these experiments with those found in similar or related work by other investigators elsewhere, though in a few instances some reference is made to such research.

DIGESTIBILITY OF FOOD.

The normal formation and expulsion of feces has commonly been considered as a process of rejecting undigested portions of food. The presence of undigested grain in the feces of domestic animals, and the frequent presence of kernels of corn, berries, and other visible particles of undigested food in the feces of men have tended to increase this impression. The ordinary chemical examination of normal feces does not, in general, present any evidence to the contrary. Nevertheless, as early as 1867 it was observed that occasionally the feces of animals contained more nitrogen than the food ingested, indicating that body nitrogen must also have been excreted in this way. The most remarkable observation of this nature on man is that recently reported by Caspari.[a] In the first period of the experiment, the subject (a vegetarian) subsisted for a period of forty-one days on a diet which contained about 1.18 grams of nitrogen and about 780 calories of energy per day. The true proteid nitrogen in the food, as determined by the Stutzer method, was about 0.86 gram per day. During this period, feces were passed with considerable regularity. The quantity of nitrogen in the feces averaged about 1.22 grams, and the energy value about 185 calories, per day. The proteid nitrogen in the feces as determined by the Stutzer method was found to average about 1.18 grams per day. The total quantity of nitrogen ingested during the period amounted to 48.58 grams, or 33.90 grams of proteid nitrogen. In the feces there were 50.28 grams of total nitrogen, of which 46.95 grams were considered proteid nitrogen. In this particular instance, then, the total fecal nitrogen was larger than the total nitrogen ingested by 1.70 grams for the period. Considering the proteid nitrogen, 13.05 grams more were found in the feces than in the food. The ingestion of food therefore actually resulted in a larger total excrétion of nitrogen through the feces than was taken in the food. In other words, the total nitrogen ingested was but 96.6 per cent of that excreted in the feces, and the true proteid intake, as determined by the Stutzer method, was but 72.2 per cent of that excreted in the feces.

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[a] Physiologische Studien Ueber Vegetarismus, Bonn, 1905.

It is thus apparent, on chemical grounds alone, that nitrogenous material other than that furnished in the food finds its way into the feces. In recent years considerable experimental evidence from various sources has accumulated to show that the feces consist in large part of the residues of the bile, mucus, saliva, and other digestive secretions and epithelial débris from the mucous lining of the whole alimentary tract. Usually the term "metabolic products" is applied to cover all these constituents of feces, but obviously it is not strictly correct to include epithelial débris under this classification. Since, however, the term has commonly been so used, this custom will be followed here to avoid confusion.

The evidence regarding the nature of the feces is in large part based upon microscopic examination, although substantiated in a considerable degree by chemical analyses. It is interesting to note in this connection the experiment of Hermann,[a] who ligated a portion of the intestine, and subsequently found material closely resembling fecal matter deposited in it even when no food had been ingested.

This observation is in accord with those on fasting men. During fasting the quantity of feces, at least with man, falls to a minimum, but the excretion of feces does not cease altogether. For example, during the thirty-day fast of Succi, as observed by Luciani,[b] but 150 grams of feces were collected. These were obtained by means of enemas. The material obtained in the enemas was evaporated to a "pasty" consistency, and weighed in this form. Luciani undoubtedly endeavored to secure a residue of normal consistency. The quantity noted is about the amount that would be normally passed in one day, and consequently it may be said that during fasting only one-thirtieth of the normal amount is excreted.

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[a] Arch. Physiol. [Pflüger], 46 (1890), p. 93.

[b] Das Hungern, 1890, p. 47.

The ingestion of food is immediately followed by a copious flow of digestive juices, the effect, as Pawlow[a] has clearly shown, partaking more or less of the nature of a series of stimulations, beginning with a psychical stimulus to the flow of the saliva, and followed by a successive flow of gastric juice and the various intestinal juices, so that the presence of food in the intestinal tract calls for the excretion of these juices. But the secretion is caused by specific constituents of the food, not by contact, and varies in kind and degree with different foods. The ingestion of a small amount of fruit by Caspari's vegetarian resulted in a marked increase in the fecal matter rejected per day as compared with the amount during fasting observed with other subjects.

Prausnitz[b] has devoted considerable attention to the special study of the feces by microscopic examination, and considers it clearly established that the digestion of food materials is more complete and the proportion of the metabolic products in the feces much larger than was formerly supposed.

The earlier work on the composition of the feces was in large part chemical, and several methods for distinguishing between the metabolic products and undigested food were proposed. Schulze and Maercker[c] suggested determining the amount of metabolic nitrogen by extracting it from the feces with boiling alcohol and boiling ether. This method receiving considerable criticism, Stutzer[d] treated feces with freshly prepared pepsin solution to remove the metabolic nitrogenous material. This method was subsequently modified and improved by Pfeiffer.[e] These methods have been subjected to considerable testing, especially at the Maine Agricultural Experiment Station,[f] and a modified method devised, which consists essentially in extracting the dried feces with boiling ether, boiling alcohol, hot water, and cold lime water, consecutively. A large number of experiments have been made by Woods and Merrill[g] with this method.

Aside from the fact that the results of all the chemical methods agree perfectly with the microscopical examinations in showing clearly that feces consist in large part of metabolic products, little more can at present be said. Unfortunately, the experimental technique is still so unsatisfactory that it is impossible for us to distinguish quantitatively between the actual undigested residues and the metabolic products. Indeed, it is commonly assumed that in the analyses of feces, when made in the usual way, all the nitrogen determined by the Kjeldahl method multiplied by the factor 6.25 is protein, the material extracted by ether is fat, the residue after incineration is ash, and the remaining water-free material is carbohydrates. Comment on the inaccuracy of this whole process is unnecessary. Revision of all chemical methods for the analysis of feces is imperatively needed.

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[a] The work of the digestive glands, London, 1902.

[b] Ztschr. Biol., 30 (1894), p. 335.

[c] Jour. Landw., 19 (1871), p. 46.

[d] Ztschr. Physiol. Chem., 10 (1886), p. 153.

[e] Ztschr. Physiol. Chem., 10 (1886), pp. 170 and 561, and Jour. Landw., 34 (1886), p. 425.

[f] Maine Expt. Sta. Rpt. 1887, p. 128; 1888, p. 210, and 1889, p. 282.

[g] U. S. Dept. Agr., Office of Experiment Stations Bul. 143, p. 58.

Although the utter inadequacy of the present methods is recognized, in the lack of more accurate knowledge it is the common custom to assume that all the fecal matter comes from the undigested portions of the food, and that the difference between the amounts of the several ingredients of the food and those of the corresponding ingredients of the feces represents the amounts of such ingredients digested.

In an attempt to anticipate the results of analyses of feces by more perfect methods, certain changes in the terminology have been proposed. According to the older conception, whereby all the ingredients of the feces were assumed to be residues from food, that portion of the food not appearing in the feces was assumed to be digested and designated as "digestible." This definition applied to the nutrients as well as to the food as a whole. As has been pointed out above, such designation is not strictly correct, because of the presence of the metabolic products. Since the metabolic products represent part of the cost of digesting food and preparing it for use by the body, Atwater[a] suggested that the word "available" be used to designate the material formerly defined as "digestible." The feces contain the total materials which the digestive organs reject; hence, if we subtract the feces from the food we have left what is, according to this conception, actually "available" to the body for the chief purposes of nutrition, namely, the building and repair of tissue and the yielding of energy. It is to be noted, however, that this proposed change in terminology throws no light on the erroneous assumptions that the nitrogenous material of the feces is proteid, or that the proportion of proteid to nonproteid nitrogen is the same in the feces as in the food; that the average composition of the ether extract of feces is conformable to the average composition of that of the food, and that the determination of carbohydrate in the feces is accurate.

In an interesting discussion of the subject Armsby[b] suggests that to avoid confusion with terms well established by long usage it is best, when strict accuracy is required, to attach a modifying word and designate the difference between the food and feces as "apparently digestible," in distinction from the "real digestibility," which can not at present be determined.

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[a] Connecticut (Storrs) Expt. Sta. Rpt. 1899, p. 69.

[b] Principles of Animal Nutrition, 1903, p. 10.

In comparing the potential energy of the food with that of the excreta still greater confusion exists, since not only is it necessary to take into consideration the difference between the energy of undigested portions of food and the energy of metabolic products, but in addition there is a considerable amount of energy in the unoxidized material in the urine, material that has undoubtedly been actually digested and absorbed. Among the qualifying terms that have been suggested to designate particular portions of the total energy of the food are "gross available" energy, meaning that portion of the total energy that can be utilized by the body for any purpose whatever, "net available" energy, which is that portion of the total energy used for other purposes than simple heat production, and "fuel value," which has the same meaning as "gross available" energy above. In discussing this point Armsby[a] suggests the term "metabolizable energy" to designate that portion of the energy of the food ingested that can enter into the metabolism of energy in the body; the term, in his opinion, expressing the facts without any implication as to the uses made by the body of the energy thus metabolized.

While fully in accord with any proposition to clarify terminology and improve technique, the writers believe that, in the present state of the whole question, it is most expedient to continue to use the method based on the common assumption that feces represent undigested material. The heat of combustion of the unoxidized material in the urine is actually determined in the majority of these experiments, and the available energy of the food, i. e., the fuel value, is considered as the total energy of the food less that of feces and urine.[b] These assumptions are almost universally followed in digestion experiments, so that the results given in the discussion beyond are comparable with those of other experiments.

With certain classes of diet it has been clearly established that there are marked differences in the real digestibility of food materials. For although, as Prausnitz[c] has pointed out, food materials should be in large measure classed not as leaving residues for feces, but as feces-producing, different food materials calling for different amounts of digestive juices and resulting in varying amounts of metabolic products, yet with certain vegetable materials, as ordinarily prepared for the table, it seems clearly established that the nitrogenous material, at least, is less readily acted upon by the digestive juices than is the case with food materials of animal origin. In the case of the legumes, for example, the cellulose may protect the proteid from the action of the digestive juices, especially if the cooking is not thorough. With the ordinary articles of human diet the preliminary preparation is usually so complete that this distinction is not so marked, but certainly in experiments with animals the evidence is very convincing.

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[a] Loc. cit., p. 270.

[b] The total energy thus computed includes both that of the muscular and other internal and external work of the body, and that transformed into heat, whether the latter results from the oxidation of food or body tissue for this specific purpose, or is liberated during the digestion, absorption, and assimilation of food.

[c] Loc. cit.

Fecal nitrogen is then a resultant of a large proportion of metabolic products and epithelial débris, and of a relatively small proportion of the ingested nitrogen. Furthermore, food materials of different nature require varying amounts of digestive juices. There is in general a much larger proportion of nitrogen in the feces from vegetable than from animal proteids. It seems fair to conclude, therefore, that the vegetable proteids are somewhat less digestible than the animal, even though the method of taking the total fecal nitrogen as a measure of the undigested proteid of the food is known to be inaccurate.

The apparent digestibility of vegetable carbohydrates and fats when compared with animal carbohydrates and fats does not show as great discrepancies as does the proteid, and while unquestionably the feces-forming property of the different foods here also plays an important rôle in determining the quantity of feces, our experimental technique is not as yet sufficiently perfected to include separations of the food residues from the intestinal débris and metabolic products. This is, of course, of most importance with fat because of the large quantity of "ether extract" in digestive juices, but it is doubtful whether any considerable quantity of body carbohydrates would be found in the feces. Since the method of determining carbohydrates is by difference, and consequently subject to the cumulative effect of all errors of analysis, little stress can be placed upon this determination. As a matter of fact, however, the quantities of carbohydrates other than crude fiber in the feces appear to be very small, and the proportion of all carbohydrates apparently digestible is correspondingly large.

RESULTS OF DIGESTION EXPERIMENTS.

A summary of the results of the digestion experiments made in connection with the metabolism experiments reported in this bulletin is given in Table 60, and for purposes of comparison the averages of results of similar nature previously reported are also included.

TABLE 60.—*Summary of the results of digestion experiments.*

Digestion experiment No.	Metabolism experiment No.	Subject and character of experiment.	Coefficients of digestibility.				Availability of energy.
			Protein.	Fat.	Carbohydrates.	Ash.	
		PRELIMINARY PERIOD.					
		Rest experiments.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
619	60	B. F. D., carbohydrate diet	91.7	96.2	97.5	74.7	90.5
		Average of 8 experiments previously reported	92.4	94.7	97.6	72.3	89.9
		Average of 9 rest experiments	92.3	94.9	97.6	72.6	90.0
		Work experiments.					
614	56	J. C. W., fat diet	89.5	94.6	96.2	56.8	91.4
616	57	J. C. W., carbohydrate diet	81.8	90.9	97.6	56.6	92.6
622	62	A. L. L., mixed diet	91.0	....	....	....	93.1
		Average of 3 experiments here reported	87.4	[a]92.8	[a]96.9	[a]56.7	92.4
		Average of 10 experiments previously reported	89.4	95.5	97.2	72.1	92.1
		Average of all (13) work experiments	88.9	[a]95.0	[a]97.1	[a]69.5	[a]92.2
		Average of 4 experiments, work and rest, here reported	88.5	[a]93.9	[a]97.1	[a]62.7	91.9
		Average of 18 experiments previously reported	90.7	95.1	97.4	72.2	91.1
		Average of all (22) experiments, preliminary period.	90.3	[a]94.9	[a]97.4	[a]70.8	91.2
		CALORIMETER PERIOD.					
		Rest experments.					
620	60	B. F. D., carbohydrate diet	89.5	95.3	97.0	66.9	89.8
625	65-67	A. L. L., carbohydrate diet[b]	94.0	94.1	98.2	58.3	88.9
		Average of 2 experiments here reported	91.8	94.7	97.6	62.6	89.4
		Average of 11 experiments previously reported	93.2	94.6	97.9	74.1	90.5
		Average of all (14) rest experiments	93.0	94.6	97.9	72.3	90.3
		Work experiments.					
615	56	J. C. W., fat diet	89.9	96.4	96.4	59.1	92.0
617	57	J. C. W., carbohydrate diet	82.9	91.8	98.1	63.5	92.8
621	61	B. F. D., carbohydrate diet	89.8	96.4	97.5	72.1	91.7
623	62	A. L. L., carbohydrate diet	85.7	96.0	97.3	53.9	92.2
624	63-64	A. L. L., fat diet	94.0	98.0	95.4	63.6	93.0
		Average of 5 experiments here reported	88.5	95.7	97.0	62.4	92.3
		Average of 21 experiments previously reported	89.5	95.9	97.7	70.4	92.6
		Average of all (26) work experiments	89.3	95.9	97.6	68.9	92.6
		Average of 7 calorimeter experiments here reported	89.4	95.4	97.2	62.5	91.5
		Average of 32 calorimeter experiments previously reported	90.8	95.5	97.8	71.7	91.9
		Average of all (39) calorimeter experiments	90.5	95.5	97.7	70.0	91.8

[a] Exclusive of digestion experiment No. 621.

[b] One day of rest, three of very light exercise.

TABLE 60.—*Summary of the results of digestion experiments*—Continued.

Digestion experiment No.	Metabolism experiment No.	Subject and character of experiment.	Coefficients of digestibility.				Availability of energy.
			Protein.	Fat.	Carbohydrates.	Ash.	
		PRELIMINARY AND CALORIMETER PERIODS.					
618	58	H. F., carbohydrate diet light exercise, and rest [a]	*Per cent.* 93.6	*Per cent.* 94.9	*Per cent.* 97.2	*Per cent.* 72.9	*Per cent.* 90.9
		Average of all (12) experiments here reported	89.5	[b] 94.9	[b] 97.2	[b] 63.5	91.6
		Average of all (50) experiments previously reported.	90.8	95.3	97.6	71.9	91.6
		Average of all (62) experiments	90.5	[b] 95.2	[b] 97.5	[b] 70.4	91.6

[a] Three days of light exercise, preliminary period, followed by three days of rest in calorimeter. No separation of feces between periods.

[b] Exclusive of digestive experiment No. 621.

For purposes of discussion the experiments are subdivided into preliminary and calorimeter periods, and into rest and work experiments. In metabolism experiment No. 58 there was no separation of feces between the preliminary and calorimeter periods, and consequently both periods are reported as a single digestion experiment. This, however, is especially advantageous, since unusual interest lies in this experiment from the dietetic habits of the subject. (See p. 84.)

Considering the experiments as a whole, it may be said that, in accord with all other observations made in this laboratory on healthy subjects, the digestion of the food was normal.

INFLUENCE OF MUSCULAR WORK UPON DIGESTIBILITY.

In discussing the effect of muscular work upon the digestibility of food, experiments to be strictly comparable should be made with the same subject living on essentially the same diet during both a rest and a work period. Since, however, with increased muscular activity a marked increase in diet is called for, and since in all experiments thus far made the primary object of the work experiments was not to study the influence of work upon digestibility, no experiments have thus far been made in the calorimeter designed for the specific object of ascertaining the influence of muscular work upon digestibility of food. Consequently any discussion of this subject must be unsatisfactory and inconclusive. Such evidence as is at hand however, is presented in Table 61. For purposes of comparison the results of earlier experiments reported in detail elsewhere are given in the same table.

In digestion experiment No. 622 (preliminary to metabolism experiment No. 62) the digestibility of fat, carbohydrates, and ash was not determined. This is due to the fact that we have come to believe that the value of the evidence from the preliminary digestion experiments is no longer sufficient to warrant the labor involved in the extra analyses and computations incidental to these determinations.

The series of preliminary periods include the results of one digestion experiment during rest, i. e., experiment No. 619 (preliminary to metabolism experiment No. 60), and three during work, Nos. 614, 616, and 622. These were followed by corresponding experiments in the respiration chamber. The averages in the table are made with a view of facilitating comparison.

The results of the preliminary periods as they stand in the table indicate that the digestibility of the protein in the work experiments was lower than that during the rest experiments, being especially low in experiment No. 57, with J. C. W. on a carbohydrate diet. The lower digestibility of protein is, however, to be ascribed not so much to the influence of muscular work upon the diet as to the character of the diet itself. A very large proportion of the protein in this diet was obtained from vegetable rather than from animal sources, and the vegetable protein in the forms in which it was usually eaten is admittedly more difficult of digestion. No noticeable differences are to be observed in the digestibility of the fat and carbohydrates in the rest and work experiments. The digestibility of ash in the two experiments with J. C. W. was unusually low. In fact, the digestibility of the ash in both experiments was lower than in any experiments thus far made in connection with the nutrition work at Middletown with the exception of No. 26, in which it was 44.4 per cent, and No. 62, in which it was 53.9 per cent. However, the incidental errors accompanying the determination of ash and the significance of its digestibility are such as not to warrant any especial discussion of this subject. In availability of energy there was a slight advantage in favor of the work experiments. It is interesting to note that this is in accord with the preliminary experiments previously reported.

Of the seven digestion experiments carried on in the respiration chamber, two were during rest and the remainder during work. Comparing the results of the rest experiment with those previously reported, it is seen that the only material variation from previous results is in the lower digestibility of the protein in experiment No. 620. This was doubtless due again to the preponderance of carbohydrates in the diet and a larger proportion of vegetable protein.

The series of experiments Nos. 65 to 67, designated as rest experiments, in reality consists of one day of rest and two of very light exercise, but the separation of the feces was such that no distinction could be made between these days.

The work experiments here reported show coefficients closely agreeing in all respects with those of experiments previously reported[a] save for a somewhat lower digestibility of ash.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 107; Connecticut (Storrs) Expt. Sta. Rpt. 1901, p. 179.

On comparing the results of the work and rest experiments and also the results of all experiments both rest and work here and previously reported, there may be noted in general a slight advantage in favor of the rest experiments with regard to the digestibility of protein, no material differences in the digestibility of fat, carbohydrates, and ash, and a slight advantage in favor of the work experiments in the availability of energy. It therefore seems reasonable to conclude that muscular work exerted no material influence on digestibility.

It is interesting to note that this conclusion is in accord with that drawn by Wait[a] and by Atwater and Sherman,[b] as a result of digestion experiments made with subjects performing severe muscular work, and also with what has been pointed out in previous reports of experiments with the respiration calorimeter.

INFLUENCE OF THE CHARACTER OF THE DIET UPON DIGESTIBILITY.

As was previously stated, several of these experiments were primarily designed to study the effect of fat as compared with carbohydrates in a diet for muscular work, consequently the diets were so chosen that the fats would preponderate during one period and carbohydrates during another. No especial attention was paid to securing the protein from a constant source and thus not alter in any way the nature of the protein supplied. As a matter of fact, in the experiments with fat diet, a large proportion of the protein was obtained from animal food, such as milk or cream, while in the carbohydrate period the larger proportion of the protein was derived from bread or other vegetable food materials. It is therefore apparent that a discussion of the effect of carbohydrate versus fat diet upon digestibility is complicated by the fact that the nature of the protein furnished is altered. Bearing this in mind, we may examine the results shown in Table 61.

TABLE 61.—*Comparison of the results of experiments with fat diet and with carbohydrate diet.*

Digestion expt. No.	Metabolism expt. No.	Subject and character of experiment.	Coefficients of digestibility.				Availability of energy.
			Protein.	Fat.	Carbohydrates.	Ash.	
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
615	56	J. C. W., work, fat diet	89.9	96.4	96.4	59.1	92.0
624	63	A. L. L., severe work, fat diet	94.0	98.0	95.4	63.6	93.0
		Average of above 2 experiments	92.0	97.2	95.9	61.4	92.5
		Average of 17 experiments on fat diet previously reported	90.6	96.7	97.0	67.4	91.7
		Average of all (19) experiments on fat diet	90.7	96.8	96.9	66.8	91.8

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[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 89, 117.
[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 98.

TABLE 61.—*Comparison of the results of experiments with fat diet and with carbohydrate diet*—Continued.

Digestion expt. No.	Metabolism expt. No.	Subject and character of experiment.	Coefficients of digestibility.				Availability of energy.
			Protein.	Fat.	Carbohydrates.	Ash.	
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
618	58	H. F., rest, carbohydrate diet	93.6	94.9	97.2	72.9	90.9
620	62	B. F. D., rest, carbohydrate diet	89.5	95.3	97.0	66.9	89.8
617	57	J. C. W., work, carbohydrate diet	82.9	91.8	98.1	63.5	92.8
621	61	B. F. D., work, carbohydrate diet	89.8	96.4	97.5	72.1	91.7
623	62	A. L. L., work, carbohydrate diet	85.7	96.0	97.3	53.9	92.2
625	65	A. L. L., light exercise, carbohydrate diet	94.0	94.1	98.2	58.3	88.9
		Average of above 6 experiments	89.3	94.8	97.6	64.6	91.1
		Average of 9 experiments on carbohydrate diet, previously reported	89.1	94.3	98.2	72.3	92.7
		Average of all (15) experiments on carbohydrate diet	89.2	94.5	97.9	69.2	92.1
		Average of 18 experiments on ordinary diet, previously reported	92.4	94.5	97.9	77.3	90.5

Two experiments, Nos. 615 and 624, were made with diets which were essentially fat. The digestibility of the protein averaged 92 per cent, which is slightly greater than in the average of seventeen previously reported experiments on a fat diet.[a] No material differences are observed in digestibility of the other constituents, aside from ash, between these results and those of earlier experiments. With the carbohydrate diet, the average of the experiments here reported agrees very closely with the results from the average of nine experiments on a carbohydrate diet as previously reported.

The average of fifteen experiments on a carbohydrate diet, including the results of six here reported and those of the nine earlier ones, when compared with the average of the nineteen experiments on fat diet, shows a very slight advantage for the latter in respect to the digestibility of protein and fat, no material differences as regards ash and energy, and a slight advantage in favor of the digestibility of carbohydrates in the carbohydrate diet.

All things considered, and especially in view of the marked alterations in the nature of the protein furnished, it is difficult to ascribe to the presence of a large proportion of either fat or carbohydrates any material influence on the digestibility of the diet as a whole. In all the experiments the variations in digestibility were slight, indicating that digestion was normal, and in no way disturbed. It might naturally be supposed that in a diet with a large preponderance of fat the proportion of fat digested would be less than in a diet where the fat was in more nearly ordinary proportions. A similar statement may be made regarding the carbohydrates. The evidence here presented shows that this is not the case, and that irrespective of the total amount of individual nutrients ingested the proportion digested remains practically constant. This is of considerable significance in any discussion of the effect of large compared with small quantities of food. (See below.) In fact a comparison of the experiments with fat and carbohydrate diets with the average of eighteen experiments on ordinary diets previously reported[a] shows that save for a slight advantage in favor of the ordinary diet so far as the digestibility of the protein is concerned, which, as explained, is due to the preponderance of vegetable protein in some of the special diets, there are no appreciable differences in the digestibility of the different nutrients, although there is a slight advantage in favor of the one-sided diets with respect to the availability of energy.

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[a] Loc. cit.

INFLUENCE OF SOJOURN INSIDE THE RESPIRATION CHAMBER ON DIGESTIBILITY.

The possible influence of confinement inside the respiration chamber on the digestibility of food is of importance and should be carefully considered. A large number of experiments were discussed in this connection in a previous report,[b] and it was there shown that the sojourn in the chamber was practically without influence on the digestibility of food. In the experiments here reported further opportunity is given for observation. Each of the present series was preceded as usual by a preliminary digestion period, though in that with H. F. no separation of feces was made, and consequently no data are available for comparing the digestibility before and after entering the respiration chamber. In experiments Nos. 62 to 67, inclusive, the analyses of the preliminary period were incomplete, there being no determinations of fat, carbohydrate, ash, or water, consequently in the discussion only the digestibility of protein and energy are here considered. From the table it is seen that the digestibility was practically the same whether the subject was inside the respiration chamber or not, indicating that the sojourn in the apparatus had no influence upon it. This fact is of no great interest so far as the digestibility of foods in general is concerned, but it has its significance in that it is one more factor to show that in these investigations the variations in the composition of the atmosphere, the restricted muscular activity in rest experiments, the limited and at times one-sided diet, and other unusual conditions apparently produced no untoward effects upon the subjects.

INFLUENCE OF THE QUANTITY OF FOOD ON DIGESTIBILITY.

The variations in the quantities of food ingested might readily be supposed to cause corresponding variations in the amount absorbed.

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[a] Loc. cit.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 109.

In a previous bulletin,[a] it was shown that there was no marked difference in the amount of food digested, whether the quantity consumed was large or small. The results of the experiments here reported confirm this view, which is in general accord with other observations,[b] where large or small diets have been fed to the same individual.

It is important to bear in mind, however, that when large diets are fed the body is almost invariably at a greater degree of activity, and consequently the digestibility may be influenced not solely by the presence of larger quantities of food in the intestinal tract, but also by muscular work. It is therefore impossible to distinguish as to which factor would affect digestibility, muscular work, or the presence of a large amount of food in the intestines. As a matter of fact, all evidence thus far accumulated goes to show that large quantities of food accompanied by increased muscular activity result almost invariably in the same proportional digestibility of the nutrients of the food as under ordinary conditions.

INFLUENCE OF PROLONGED MASTICATION OF FOOD ON DIGESTIBILITY.

It has long been a popular opinion that the thorough mastication of food tends toward a more complete digestion of it, and this theory has been especially advocated by Fletcher [c] in recent years. In connection with the experimental work in this laboratory, opportunity has been had in a number of instances to observe the effect of little chewing as compared with that of thorough mastication upon digestibility. A large number of feces have been examined, but we have rarely found unaltered material of sufficient magnitude to enable us to assert from macroscopic examination that it was undigested food. In one series, with a number of students, rather large pieces of meat were found in the feces of one subject, who had literally bolted his food. In a study by Atwater and Benedict of the food consumed by members of the Harvard University crew,[d] it was found that when canned corn was included in the diet, large portions of it passed through the alimentary tract unaltered, and indeed with remarkable rapidity. In this instance the presence of the undigested corn clearly established a diarrhea, which was subsequently checked by eliminating corn from the diet.

In this connection digestion experiment No. 618 with H. F. is of considerable interest. This subject for years has practiced masticating his food to such an extent as to secure unusual thoroughness of comminution and insalivation in the belief that he has thereby increased the economy and completeness of digestion and improved his bodily health and general vigor. As regards thoroughness of digestion, no especial advantage accrued from the practice in this investigation, however, according to the data summarized in Table 60. The results of this experiment are practically identical with the average of the results of all twelve included in the table, and also with the average of sixty-two experiments, including these twelve and the fifty others made in connection with earlier metabolism experiments and previously reported. The digestibility of protein in the experiment with H. F. was a little higher than the average, but the difference is not particularly significant. Furthermore, this is but one experiment with this subject in comparison with so many others with a considerable number of different subjects; among those are several in which the digestibility of the protein is equal to that in No. 618. In fact, in experiment No. 625, given in the table on page 129, in which the conditions as regards diet, bodily activity, etc., were more comparable with those in No. 618 than was true of any of the other experiments here reported, the subject digested a trifle larger proportion of the protein, though he paid no special attention to thoroughness of mastication. The comparison of the results of experiment No. 618 with those of any of the other experiments is always necessarily modified by the fact that, as explained on page 90, the final separation of feces in the investigation with H. F. was not made in this laboratory, and it is our impression that the total amount collected was smaller than what should be ascribed to the experimental diet. In such a case the coefficients of digestibility of the nutrients for this subject would be somewhat smaller than is shown in Table 60.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136.

[b] U. S. Dept. Agr., Office of Experiment Stations Buls. 89, 117.

[c] A. B.-Z. of Our Own Nutrition. Horace Fletcher, New York [1903].

[d] Boston Med. and Surg. Jour. 144, p. 629.

In other digestion experiments conducted in this laboratory in which the diet consisted also of milk, sugar, and the cereal breakfast food such as used by H. F., though in larger amounts, the comparative digestibility was noted for two subjects, one of whom masticated his food much more thoroughly than the other. The results have been published in full elsewhere.[a] In these experiments the subject who ate the cereal somewhat rapidly actually digested more of the total organic matter of the diet than the subject who masticated it much more completely. It would seem that thorough mastication should have been especially effective in increasing the digestibility of the breakfast food used, which was a dry "ready to eat" variety and unless it were very finely divided by chewing would naturally resist to a certain extent the action of the digestive juices; but there was little evidence that it appreciably increased the completeness of digestion. It may have had some effect upon the ease or rapidity of digestion, but that is another matter, which was not studied in these investigations, and has been rarely studied for both stomach and intestines, though popular statements concerning it are not uncommon.

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[a] Connecticut (Storrs) Expt. Sta. Rpt. 1904, p. 199.

GENERAL CONCLUSIONS REGARDING DIGESTION OF FOOD.

From the results of a large number of digestion experiments, including not only those made in this laboratory in connection with the investigations in the respiration calorimeter and in the study of problems of nutrition not involving experiments with this apparatus, but also those forming part of the other cooperative nutrition investigations of this Office, and those made by other investigations elsewhere, it is evident that different kinds of foods differ materially in respect to the digestibility of their nutrients, especially protein. The protein of animal foods like meat and milk is more completely digested and utilized than that of most vegetable foods, like beans or coarse cereal products. But it would appear that a given kind of food material is digested, within reasonable limits, with equal thoroughness by different individuals with normal digestive functions, irrespective of differences in the amount of food, completeness of mastication, muscular activity, or environment of the subjects. It would also appear that when the common food materials make up the diet in proportions in which they are ordinarily used, in general at least 95 to 96 per cent of the total organic matter is digested and utilized by the body. With such an average efficiency there is little opportunity for improvement in the thoroughness of digestion of the ordinary diet. Any dietetic practice, therefore, such as excessive mastication, which may be claimed to result in greater economy in the utilization of food so far as it relates to thoroughness of digestion, must improve upon a condition in which there is already almost complete utilization.

It is by no means to be inferred that incomplete mastication is recommended. At least an ordinary amount of chewing is necessary. Bolted food frequently irritates the intestines, as has been pointed out, and hasty eating should never be practiced. Thorough mastication is always advisable. The desire is simply to show that the prolonged mastication sometimes advocated does not result in any greater economy in the utilization of food. Indeed, on the basis of energy, it may reasonably be questioned whether the muscular work incidental to excessive chewing may not actually result in a waste of energy. This is a question worthy of investigation. It is also very desirable to ascertain to what extent thorough chewing increases the ease or rapidity of digestion, and the result of this upon nutrition and bodily comfort and well-being.

COMPOSITION OF FECES.

The percentage composition of the feces pertaining to the metabolism experiments here reported is given in Table 62.

TABLE 62.—*Average percentage composition and heat of combustion of water-free and water- and ash-free substance of feces in metabolism experiments Nos. 56–58 and 60–67.*

Subject and character of experiment.	Duration.	In water-free substance.						In water- and ash-free substance.				
		Nitrogen.	Carbon.	Hydrogen.	Oxygen by difference.	Ash.	Energy per gram.	Nitrogen.	Carbon.	Hydrogen.	Oxygen by difference.	Energy per gram.
Fat diet.												
	Days.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Cals.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Cals.*
J. C. W., experiment, work, 56	3	3.71	55.35	8.42	13.71	18.81	6.381	4.57	68.17	10.37	16.89	7.859
A. L. L., 2 experiments, work, 63, 64	4	2.83	50.45	7.55	15.38	23.79	5.877	3.71	66.20	9.91	20.18	7.712
Average of 3 experiments, fat diet	7	3.21	52.55	7.92	14.66	21.66	6.093	4.08	67.04	10.11	18.77	7.775
Carbohydrate diet.												
J. C. W., 1 experiment, work, 57	3	5.57	48.39	6.64	24.63	14.77	5.134	6.54	56.76	7.79	28.91	6.024
H. F., 1 experiment, work, 58	3	2.95	46.23	6.33	24.56	19.93	4.932	3.68	57.74	7.91	30.67	6.160
B. F. D., 1 experiment, work, 60	3	5.86	45.73	6.08	24.23	18.10	4.491	7.16	55.84	7.42	29.58	5.484
B. F. D., 1 experiment, work, 61	1	5.34	50.28	7.03	20.88	16.47	5.241	6.39	60.19	8.42	25.00	6.274
A. L. L., 1 experiment, work, 62	3	4.87	45.46	5.84	25.34	18.49	4.832	5.97	55.77	7.16	31.10	5.928
A. L. L., 3 experiments, rest	4	3.97	37.78	5.14	16.53	36.58	4.253	6.26	59.57	8.10	26.07	6.706
Average of 8 experiments, carbohydrate diet	17	4.65	44.64	6.01	22.54	22.16	4.731	5.97	57.46	7.74	28.83	6.111
Average of 11 experiments here reported	24	4.23	46.95	6.57	20.24	22.01	5.128	5.42	60.25	8.43	25.90	6.596
Average of 47 experiments previously reported	145	5.33	48.38	6.71	20.79	18.79	5.377	6.54	59.58	8.34	25.54	6.623
Average of all (58) experiments, all diets	169	5.17	48.18	6.69	20.71	19.25	5.342	6.38	59.68	8.35	25.59	6.619

For purposes of comparison with the previously reported experiments, the composition is computed on the basis of the water-free substance and likewise on the water- and ash-free or organic substance. In the experiments previously reported[a] the composition of feces was tabulated for the subjects irrespective of diet, although distinction was made between rest and work experiments. Variations in the composition of the feces, however, appear to be due not to differences in individuals, but to differences in the character of the diet, and hence in the experiments here reported the latter factor is the basis of the subdivision.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 115.

The experiment with J. C. W. and two experiments with A. L. L., covering a total of seven days, had a preponderance of fat in the diet. The percentage of nitrogen is considerably lower in the feces from the fat diet, the percentage of carbon and hydrogen higher, the oxygen by difference lower, and no material difference in the ash. The energy was considerably higher in the feces on the fat diet. This is more markedly shown when the computations are based on the amount of organic substance in the feces—i. e., deducting the water and ash. The low percentage of nitrogen, and of oxygen by difference, the high percentage of carbon and hydrogen, and the energy per gram in the fat diet, when compared with the carbohydrate diet, are very noticeable.

Of the experiments on a carbohydrate diet, that of H. F. shows the greatest abnormalities. Here the percentage of nitrogen is low, and indeed lower when considered on the basis of organic material than the percentage of nitrogen in the experiments with fat diet. Aside from the very low percentage of nitrogen, however, no other marked variations from the normal are to be observed in the feces of this experiment. This is probably in large part accounted for by the fact that the total amount of nitrogen ingested was about one-half that consumed by the subjects of the previously reported experiments. Comparing the results of the experiments of the fat diet it is seen that the percentage of nitrogen is considerably smaller in these experiments than in the earlier ones, while those of carbon, hydrogen, and oxygen are somewhat less, and the ash considerably higher. The energy per gram is somewhat lower. This is still more noticeably brought out when computations are based on the organic material present. In the average of the eight experiments with carbohydrate diet here reported, the percentage of nitrogen, carbon, hydrogen, and oxygen by difference, as well as the energy per gram is considerably lower, while the ash content is very much higher, than in that of the six work experiments previously reported.[a] When computed on the basis of organic substance, the percentage of nitrogen still remains considerably lower, but the discrepancies in the percentage of carbon, hydrogen, oxygen by difference, and energy per gram practically disappear.

The marked increase in the ash content on the average of the eight experiments here reported with carbohydrate diet is due almost wholly to the abnormally high ash content for the four days of the three rest experiments with A. L. L., for which the percentage of ash in water-free substance was 36.58, twice the average for the other five experiments. It is interesting to note that in spite of this high ash content, the energy per gram when computed on the water- and ash-free basis is not far from that found in all the experiments with the carbohydrate diet.

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[a] Loc. cit.

An inspection of the figures shows no very great abnormalities regarding the composition of the feces other than those two mentioned above, namely, low nitrogen content of the feces of H. F. and high ash content of the feces of A. L. L. during the rest experiment, and the evidence as here set forth would indicate that the influence of the individual upon the composition of the feces is very much less than that of the character of the diet, and that likewise the difference between rest and work is not great, providing the character of the diet is the same in both instances.

In Table 63 the relation of the other elements to nitrogen, and of energy to organic matter, nitrogen, and carbon, in the feces is shown.

TABLE 63.—*Relation of other elements to nitrogen, and of energy to organic matter, nitrogen, and carbon, in feces in metabolism experiments Nos. 56–58 and 60–67.*

Subjects and character of experiments.	Duration.	Amounts per gram of nitrogen.				Energy per gram of—		
		Carbon	Hydrogen.	Oxygen (by difference).	Organic substance.	Organic substance.	Nitrogen.	Carbon.
Rest experiments.								
H. F., experiment No. 58, carbohydrate diet	*Days.* 3	*Grams.* 15.69	*Grams.* 2.15	*Grams.* 8.33	*Grams.* 27.17	*Calories.* 6.16	*Calories.* 167.39	*Calories.* 10.67
B. F. D., experiment No. 60, carbohydrate diet	3	7.80	1.04	4.13	13.97	5.48	76.59	9.82
A. L. L., experiments Nos. 65, 66, and 67, carbohydrate diet	4	9.52	1.29	4.16	15.97	6.71	107.12	11.26
Average of 5 rest experiments	10	10.86	1.47	5.40	18.73	6.18	116.04	10.65
*Work experiments.**								
J. C. W., experiment No. 56, fat diet	3	14.91	2.27	3.70	21.88	7.86	171.97	11.53
J. C. W., experiment No. 57, carbohydrate diet	3	8.68	1.19	4.42	15.29	6.02	92.11	10.61
B. F. D., experiment No. 61, carbohydrate diet	1	9.42	1.32	3.91	15.65	6.27	98.18	10.42
A. L. L., experiment No. 62, carbohydrate diet	3	9.34	1.20	5.21	16.75	5.93	99.30	10.63
A. L. L., experiments Nos. 63 and 64, fat diet	4	17.84	2.67	5.44	26.95	7.71	207.87	11.65
Average of 6 work experiments	14	12.83	1.86	4.69	20.38	6.90	144.27	11.09
Average of 11 experiments here reported	24	12.01	1.70	4.99	19.70	6.60	132.51	10.91
Average of 47 experiments previously reported	145	9.23	1.29	3.93	15.45	6.67	102.73	11.14
Average of all experiments	169	9.62	1.35	4.08	16.05	6.66	106.96	11.11

It is highly desirable, if possible, to secure some standard factors which can be used for computing some of the data regarding feces. In the report of earlier experiments[a] it was pointed out that the amounts of carbon, hydrogen, oxygen, and organic substance per gram of nitrogen varied considerably in feces from different individuals on different diets. This conclusion seems substantiated by the results of the experiments reported herewith. For example, the amount of carbon per gram of nitrogen ranges from 7.80 grams in experiment No. 60, with B. F. D. on a carbohydrate diet, to 17.84 grams in experiments Nos. 63 and 64, with A. L. L. on a fat diet, and averages 12.01 grams for all eleven of the experiments. In the five rest experiments the average was 10.86 grams, and in the six work experiments 12.83 grams. The marked variation in this ratio of carbon to nitrogen in feces is still more clearly shown by the fact that in the average of forty-seven experiments previously reported there were 9.23 grams of carbon per gram of nitrogen. Obviously the ratio is not at all well established. What is true regarding carbon is true in a similar measure regarding hydrogen, oxygen, and organic substance. It therefore seems practically impossible to establish any ratios for use in computing the quantity of carbon, hydrogen, oxygen, and organic substance from the amount of nitrogen in feces.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 116.

The ratio of the energy of the feces per gram of organic substance, nitrogen, and carbon is a little more definite. In the case of organic substance the results in the experiments here reported range from 5.48 calories per gram in experiment No. 60 to 7.86 calories in experiment No. 56, averaging in the rest experiments 6.18 calories and in the work experiments 6.93 calories per gram of organic substance. The two experiments with fat diet increased the average in the work experiments. If the average of experiments Nos. 57, 61, and 62, which were all on carbohydrate diet, is taken, there is practically no difference between the results for rest and work experiments. The fact that this ratio is a fairly constant one is shown by a comparison with the average of forty-seven experiments previously reported, in which the energy per gram of organic substance is 6.67 calories, as compared with 6.60 calories in the average of the eleven experiments here reported.

Much less concordant are the results as to the average energy per gram of nitrogen, which ranges from 76.59 calories in the case of experiment No. 60 to 207.87 calories in experiments Nos. 63 and 64. The average for the eleven experiments here reported is 132.51, as against 102.73 calories of the forty-seven experiments previously reported. Here again no ratio can be said to be established.

On the contrary, the data regarding the energy per gram of carbon show much greater concordance. The variations range from 9.82 calories in experiment No. 60 to 11.65 in experiments Nos. 63 and 64, with an average of 10.65 for the five rest experiments, and 11.09 for the six work experiments, or 10.91 for the eleven experiments here reported. This ratio is very close to that of the forty-seven experiments previously reported—i. e., 11.14. It is to be observed again that the ratio is larger in the experiments in which the fat diet predominated, and although the averages agree quite closely, the ratio is only an approximation. While the data do not show the composition of feces and the ratio of the different elements and energy with different persons on exactly the same diet, they tend to show that, at least so far as the ratio of carbon to energy is concerned, the amount of energy per gram of carbon in feces is not far from 11 calories. The effect of the character of the diet on this ratio, however, must not be lost sight of in computing the energy from the carbon content of feces.

The energy per gram of organic substance in feces is of interest since the results show much wider variations than are reported by Rubner.[a] His values range, for 1 gram of organic material, from 6.061 to 6.357 calories, when the average diet is used. With a meat diet the energy increases to 6.403 calories per gram. In the experiments here reported, with a fat diet, the energy may reach 7.86 calories, while, with a carbohydrate diet, one experiment gave a result of 5.48 calories. The average of all the experiments—6.66 calories—is considerably higher than those reported by Rubner. This is undoubtedly due to the fact that a large number of the experiments were made with a fat diet, in which the energy per gram of organic substance is much higher than with the ordinary mixed diet. The average of the experiments with a carbohydrate diet is much more nearly in accord with the figures presented by Rubner.

COMPOSITION OF URINE.

While the ordinary urine analyses consist mostly of determinations of urea, uric acid, phosphates, sulphates, and pigments and abnormal constituents, yet for metabolism experiments, especially those in which the income and outgo of energy are involved, these analyses are not adequate. According to the method of experimenting employed in connection with the respiration apparatus, the analyses of urine which are of greatest value are those in which determinations of water, ash, or mineral matter, nitrogen, carbon, hydrogen (organic) and heat of combustion are made. These values are used in computing the gains or losses of material in the body and the transformations of energy, since a portion of the ingested protein is excreted in the urine as unoxidized material, such as urea, uric acid, and other nitrogenous compounds. For clinical purposes the amounts of uric acid, urea, phosphates, sulphates, etc., and the ratios between these, are of extreme importance. Similarly, ratios between the different elements and the energy are of great importance in computing the outgo of both matter and energy in the urine. Thus if it could be clearly established that there was a constant amount of energy, carbon, and organic hydrogen per gram of nitrogen in urine, the determination of these elements could in many experiments be dispensed with. Accordingly the data of the experiments here reported have been tabulated and the various ratios have been carefully computed. Table 64 shows the average percentage composition of the water- and ash-free substance of urine in both rest and work experiments, since some slight differences have been noted in the urine resulting from these two different classes of experiments in former reports.

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[a] Die Gesetze des Energieverbrauchs bei der Ernahrung, p. 35.

TABLE 64.—*Average percentage composition of water- and ash-free substance of urine in metabolism experiments Nos. 56–58 and 60–67.*

Subject and character of experiment.	Duration.	In water- and ash-free substance.			
		Nitrogen.	Carbon.	Hydrogen.	Oxygen (by difference).
Rest experiments.	*Days.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
H. F., experiment No. 58	3	30.53	26.90	6.61	35.96
B. F. D., experiment No. 60	3	33.03	29.34	6.84	30.79
A. L. L., experiments Nos. 65, 66, and 67	4	36.68	24.44	6.36	32.52
Average of 5 experiments here reported	10	33.74	26.65	6.58	33.03
Average of 22 rest experiments previously reported	67	34.68	24.28	6.68	34.36
Average of all (27) rest experiments	77	34.56	24.59	6.67	34.19
Work experiments.					
J. C. W., experiment No. 56	3	36.72	29.75	7.51	26.02
J. C. W., experiment No. 57	3	36.36	29.49	7.76	26.39
B. F. D., experiment No. 61	1	34.70	27.09	7.06	31.15
A. L. L., experiment No. 62	3	32.95	26.77	6.31	33.97
A. L. L., experiment No. 63	3	33.82	25.59	6.76	33.83
A. L. L., experiment No. 64	1	32.78	24.46	6.88	35.88
Average of 6 experiments here reported	14	34.79	27.59	7.07	30.55
Average of (25) work experiments previously reported	78	32.28	23.76	6.61	37.35
Average of all (31) work experiments	92	32.66	24.34	6.68	36.32
Average of 11 work and rest experiments here reported	24	34.35	27.20	6.87	31.58
Average of 47 rest and work experiments previously reported	145	33.39	24.00	6.64	35.97
Average of all (58) rest and work experiments	169	33.53	24.46	6.67	35.35

The variations in the percentage of nitrogen are noticeable, ranging from 30.53 in the case of experiment No. 58 to 33.72 in experiment No. 56. The average of the five rest experiments here reported is slightly lower than that of twenty-two rest experiments previously reported, and also slightly lower than the average of six work experiments here reported. On the contrary the average of eleven work and rest experiments here reported is considerably above that of the work experiments previously reported, and about 1 per cent above that of the work and rest experiments previously reported.

The fluctuations in the percentages of carbon are about equally great. The percentage of carbon as determined in these experiments is materially higher than in earlier work, due in all probability to improved technique.

The variations in the organic hydrogen show a noticeably greater amount of hydrogen in the urine from the work experiments than from those in the rest experiments and a slightly greater average in the urines from all the experiments here reported as compared with those of the previous experiments.

The oxygen by difference is added to this table principally because it is used in subsequent calculations. Obviously, since it is affected by the algebraic sum of the errors on the determinations of all the other elements, no great significance can be attached to the variations in percentages occurring in the different experiments. Since, however, the experimental technique has been improved on all the determinations, it is reasonable to suppose that the errors in the estimations of the oxygen by difference are less in these than in the previously reported experiments, and we find that the average of the experiments here reported is 31.53 per cent of oxygen as against 35.97 in the forty-seven previously reported experiments.

Table 65 shows the relation of the other elements to nitrogen and of energy to organic matter, nitrogen, and carbon.

TABLE 65.—*Relation of other elements to nitrogen and of energy to organic matter, nitrogen, and carbon, in urine, in metabolism experiments Nos. 56–58 and 60–67.*

Subject and character of experiment.	Duration.	Amounts per gram of nitrogen.				Energy per gram of—		
		Carbon.	Hydrogen.	Oxygen by difference.	Organic substance.	Organic substance.	Nitrogen.	Carbon.
Rest experiments.	*Days.*	*Gram.*	*Gram.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
H. F., experiment No. 58	3	0.881	0.217	1.178	3.276	2.729	8.937	10.143
B. F. D., experiment No. 60	3	.888	.207	.932	3.027	2.725	8.252	9.288
A. L. L., experiment Nos. 65, 66, and 67	4	.666	.173	.887	2.726	2.679	7.303	10.961
Average of 5 experiments here reported	10	.797	.196	.988	2.981	2.708	8.078	10.214
Average of 22 rest experiments previously reported	67	.701	.193	.994	2.888	2.761	7.974	11.375
Average of all (27) rest experiments	77	.713	.193	.993	2.899	2.754	7.988	11.224
Work experiments.								
J. C. W., experiment No. 56	3	.810	.205	.709	2.724	3.245	8.835	10.907
J. C. W., experiment No. 57	3	.811	.213	.726	2.750	3.165	8.705	10.731
B. F. D., experiment No. 61	1	.781	.203	.898	2.882	2.910	8.384	10.739
A. L. L., experiment No. 62	3	.812	.192	1.031	3.035	2.795	8.483	10.444
A. L. L., experiment No. 63	3	.757	.200	1.000	2.957	2.582	7.635	10.089
A. L. L., experiment No. 64	1	.746	.210	1.095	3.051	2.676	8.163	10.940
Average of 6 experiments here reported	14	.793	.203	.885	2.881	2.925	8.394	10.585
Average of 25 work experiments previously reported	78	.738	.205	1.171	3.114	2.610	8.104	10.981
Average of all (31) work experiments	92	.746	.205	1.127	3.078	2.658	8.148	10.921

TABLE 65.—*Relation of other elements to nitrogen and of energy to organic matter, nitrogen, and carbon, in urine, in metabolism experiments Nos. 56–58 and 60–67*—Cont'd.

Subject and character of experiment.	Duration.	Amount per gram of nitrogen.				Energy per gram of—		
		Carbon.	Hydrogen.	Oxygen by difference.	Organic substance.	Organic substance.	Nitrogen.	Carbon.
Work experiments—Continued.								
Average of 11 work and rest experiments here reported	*Days.* 24	*Gram.* 0.795	*Gram.* 0.200	*Grams.* 0.928	*Grams.* 2.923	*Calories.* 2.835	*Calories.* 8.262	*Calories.* 10.430
Average of 47 rest and work experiments previously reported	145	.721	.200	1.089	3.010	2.680	8.065	11.047
Average of all (58) rest and work experiments	169	.731	.200	1.066	2.997	2.702	8.093	10.959

As pointed out above, these ratios are of especial significance in the estimation of the amount of carbon, hydrogen, and energy from the quantity of nitrogen or carbon in the urine in many experiments in which complete analyses can not be made. As regards the amount of carbon per gram of nitrogen, in the majority of experiments the variations were not very great, the lowest being that of experiments Nos. 65, 66, and 67, in which there was 0.666 gram of carbon per gram of nitrogen, and the highest being that of experiment No. 60, in which there was 0.883 gram. The average of the five rest experiments here reported was 0.797, against 0.701 for twenty-two rest experiments previously reported. The average of the five rest experiments is practially the same as that of the six work experiments, thus showing no difference between the rest and work experiments so far as the ratio of carbon to nitrogen is concerned. It would thus appear that for every gram of nitrogen in the urine there is about three-fourths of a gram of carbon. The ratio of the organic hydrogen is very constant. Excepting the experiments Nos. 65, 66, and 67, the results are all very close to 0.20, averaging for the five rest experiments here reported 0.196, and for the six work experiments 0.203; consequently it is fair to assume that for every gram of nitrogen there will be one-fifth of a gram of organic hydrogen. The same conditions that affect the determination of the oxygen by difference mentioned above, simultaneously affect the ratio of oxygen and nitrogen, hence little stress can be laid upon this ratio. With the organic substance, on the other hand, the ratio seems quite constant, there being about 3 grams of organic substance to each gram of nitrogen in the rest experiments, as against 2.881 grams in the work experiments. An average of all the experiments shows that in general each gram of nitrogen corresponds to 3 grams of organic substance.

With regard to the ratio between the energy and the amount of organic substance, nitrogen, and carbon, the ratios are again quite satisfactorily established, showing that for every gram of organic substance there are about 2.7 calories of energy. With the ratio between the organic substance and amount of nitrogen quite fixed and that between the organic substance and the energy fairly constant, it follows that the ratio between the nitrogen and the energy is a reasonably constant one, and it may be said that for every gram of nitrogen in the urine there are about 8 calories of energy. It must not be forgotten, however, that in certain experiments, especially Nos. 65 to 67, with A. L. L., the ratio was much lower, approximately 7.3 calories per gram of nitrogen.

In the experiments previously reported the amount of energy per gram of carbon was found to be very constant—i. e., about 11 calories per gram. In the experiments here reported there were variations from 9.288 calories in experiment No. 60 to 10.961 calories in experiments Nos. 65 to 67; but the maximum in the experiments here reported does not reach the average of the previously reported experiments, these showing a much lower average heat of combustion and energy per gram of carbon than in the earlier work experiments. In fact, the average of the eleven work and rest experiments here reported, covering twenty-four days, is 10.43 calories per gram of carbon, a material diminution from the average of the forty-seven rest and work experiments previously reported, covering one hundred and forty-five days, which give 11.047 calories of energy per gram of carbon. This only serves to show that while the ratios between the elements and nitrogen and between the energy and the organic substance or nitrogen or carbon are fairly constant, they can not be relied upon for accurate computations, and can in no wise take the place of actual determinations in metabolism experiments where great accuracy is desired.

NITROGEN IN PERSPIRATION.

While it is commonly assumed that no nitrogen is eliminated from the body other than through the urine and feces, a considerable amount of experimental evidence has accumulated to show that there may be appreciable quantities of nitrogenous material excreted through the skin in the perspiration. Most of the earlier researches upon this point showed that the quantities thus eliminated were very small, in fact entirely negligible in ordinary nitrogen metabolism experiments. Where the perspiration is not excessive, as in rest experiments, the amount is, by actual experiment, found to be slight. On the contrary, when profuse perspiration is induced, either by muscular work, by excessive temperature, or by drugs, there is a relatively large amount of nitrogen excreted through this channel. A discussion of this point has recently been presented by one of us[a] in which considerable evidence, obtained by experiments with a professional bicycler since the investigations here reported were made, is given to show that during muscular work the amount of nitrogenous material eliminated through the skin may be sufficient to yield as high as 0.22 gram of nitrogen per hour.

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[a] Jour. Biol. Chem., 1 (1905), p. 263.

During the experiments the subject dresses only in underclothing and stockings which have previously been freed of soluble nitrogenous material by repeated rinsing in distilled water. Before the experiment begins the body of the subject is thoroughly washed and finally rinsed with distilled water. The underclothing and stockings are then put on, and at the end of the experiment the body is again thoroughly washed and rinsed in distilled water. The clothes are extracted in eight successive changes of water. The extract water from the clothes and the water in which the body is washed at the end of the experiment are then acidified, evaporated to small bulk, and aliquot portions subjected to the usual Kjeldahl process for the determination of nitrogen. In a number of work experiments reported in an earlier publication,[a] the average amount of nitrogen eliminated per day in perspiration was about 0.29 gram, although there were fluctuations from 0.20 to 0.66 gram. In the experiment with the professional bicycler referred to above, excessive work was performed for periods of four hours, and the total excretion of nitrogen for the four-hour period was found to be 0.87 gram.

In the work experiments reported in this bulletin, the nitrogen eliminated in the perspiration was determined, but unfortunately the analytical data for experiments Nos. 62, 63, and 64 are lacking because an accident to the distillation flask resulted in a loss of material. The results from experiments Nos. 56, 57, and 61 are given in Table 66.

TABLE 66.—*Nitrogen eliminated in perspiration in work experiments.*

	Duration.	Total nitrogen.	Average per day.
	Days.	*Grams.*	*Gram.*
Experiment No. 56	3	1.9500	0.6500
Experiment No. 57	3	1.9200	.6400
Experiment No. 61	1	.7883	.7883
Total of 3 experiments here reported	7	4.6583	.6655
Total of 25 work experiments previously reported	88⅝	25.6500	.2900
Total of 28 work experiments	95⅝	30.3083	.3169

In these experiments the amount of nitrogen eliminated through this channel averaged per day 0.6655 gram, with a minimum of 0.6340 and a maximum of 0.7883 gram. This average is, as a matter of fact, higher than any individual determinations in previously reported experiments, where the maximum amount per day was 0.66 gram. The amount of muscular work performed in experiments Nos. 56, 57, and 61, was, however, considerably greater than that performed in many of the earlier work experiments, and the increased amount of nitrogen determined in the perspiration is probably due to this and to the fact that greater care was exercised in washing the body before and after the experiment, and in extracting the underclothing.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 118.

It is thus apparent, from the results of these and earlier experiments, that during muscular work considerable quantities of nitrogen may be excreted through the skin. This should not be neglected in accurate experiments on the metabolism of protein. The error resulting from the neglect of nitrogen excretion becomes still more noticeable when the quantities of nitrogen in the food and urine and feces are smaller than normal. It is further to be noted that the results here presented represent minimum rather than maximum figures for the conditions of muscular activity of these experiments, since there is in all probability a constant loss of nitrogen from the decomposition of ammonia-containing compounds on the skin.

ERROR INVOLVED IN NEGLECTING THE NITROGEN IN PERSPIRATION.

As stated above, the amount of nitrogen eliminated in perspiration in experiments Nos. 62–64 was not determined. Since it is the purpose in these reports to publish results based in so far as possible upon observation rather than upon estimation, the gain or loss of body material and energy given in the discussion of experiments Nos. 62–64 on preceding pages was that computed with no allowance for the cutaneous excretion of nitrogen. In order to show the probable error in neglecting the nitrogen eliminated in this way, the average gain or loss of body material on the second day of experiment No. 63, as thus computed, is compared in the following table with the similar data calculated with an allowance for nitrogen in perspiration.

From data obtained in earlier experiments, it seems fair to assume that the subject eliminated 0.64 gram of nitrogen per day through the skin. This is based upon actual determination with the subject J. C. W. This subject is somewhat larger than A. L. L., and both the total energy of material oxidized in the body and the heat equivalent of the external muscular work were somewhat greater in experiments with the former than in those with the latter, consequently it may be thought that the value is somewhat larger than would normally be expected from a smaller subject, performing less work. On the other hand, since the method of determining the cutaneous excretion of nitrogen gives results that probably represent the minimum rather than the maximum figure, it seems reasonable to use, in the calculations in which the nitrogen of perspiration is taken into account, a value which perhaps more nearly agrees with the true excretion.

TABLE 67.—*Gain or loss of protein, fat, carbohydrates, and water as calculated without and with allowance for nitrogen of perspiration, metabolism experiment No. 63, second day.*

Method of calculation.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Protein.	Fat.	Carbohydrates.	Water.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Without allowance for nitrogen of perspiration....	−3.27	−43.62	−77.19	−554.42	−19.62	−63.38	+33.57	−629.37
With allowance for nitrogen of perspiration.......	−3.91	−43.62	−77.12	−553.85	−23.46	−61.81	+35.45	−629.04

The most important effect is that upon the protein loss, which is nearly 4 grams larger when the nitrogen of perspiration is taken into account. Since the quantity of nitrogen enters into account in each of the formula by which the body compounds are computed (see p. 72) and only the quantity of nitrogen is changed, those of the other three elements remaining the same, the computed gains or losses of the other compounds are of course also affected. The difference in the results for water are negligible, but the loss of fat was apparently about 2 grams less and the gain of carbohydrates about 2 grams more when the correction for nitrogen only is made. The latter changes, however, are perhaps not exact. The nitrogen was not eliminated as such, but in some compound, possibly resembling urea, comprising also carbon, hydrogen, and oxygen. The quantities of these elements used in the above-mentioned formulæ should also be corrected for those in the perspiration, and this would probably affect the gain or loss of fat and carbohydrates. But the exact nature of the nitrogen compound of the perspiration is not known, and the estimation of its content of these elements would be a pure speculation; hence they are neglected. The error involved in this, however, is probably of much less importance than that in disregarding the nitrogen.

The effect of this correction on the gain or loss of energy is nothing, according to the above calculation, with no allowance for the other elements accompanying the nitrogen. Thus the extra loss of protein involves a loss of 22 calories more than was computed without the allowance for nitrogen of perspiration; but with the change in the gain or loss of fat and carbohydrates there was appparently 15 calories less lost in fat and 8 calories more gained in glycogen, making a total of 23 calories to balance the increase of 22 calories in the protein lost. This balance, however, would be affected by the probable changes in the gain or loss of fat and glycogen if allowance could be made for the quantities of the other elements besides nitrogen lost in the perspiration.

SUMMARY OF DATA OF INCOME AND OUTGO.

The average daily income and outgo of nitrogen and carbon in the separate experiments is shown in Table 68. The income of nitrogen, for example, is that in the food and the outgo that in the feces and urine; in the case of carbon the balance is between the amount received in the food and the sum of the quantities in the excreta and respiratory products. Corresponding data for hydrogen and oxygen are given in Table 69. In Table 70 the amounts of body material gained or lost and the balance of income and outgo of energy are included.

TABLE 68.—*Summary of average daily income and outgo of nitrogen and carbon.*

Subject and kind of experiment.	Duration.	Nitrogen.				Carbon.				
		(*a*) In food.	(*b*) In feces.	(*c*) In urine.	(*d*) Gain (+) or loss (−), *a*−(*b*+*c*).	(*e*) In food.	(*f*) In feces.	(*g*) In urine.	(*h*) In respiratory products.	(*i*) Gain (+) or loss (−), *e*−(*f*+*g*+*h*).
Rest experiments.	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 58, with H. F., carbohydrate diet	3	6.66	0.40	8.47	−2.21	150.87	6.28	7.46	179.90	− 42.77
No. 60, with B. F. D., carbohydrate diet	3	16.79	1.72	15.71	− .64	250.09	13.41	13.96	212.71	+ 10.01
Nos. 65–67, with A. L. L., carbohydrate diet	4	12.89	.85	20.30	−8.26	216.63	8.13	13.53	242.62	− 47.65
Average of Nos. 58, 60, 65–67	10	12.19	.98	15.37	−4.16	206.94	9.16	11.84	214.83	− 28.89
Work experiments.										
No. 56, with J. C. W., fat diet	3	18.69	1.80	*16.31	+ .59	519.12	26.80	12.68	480.59	− .95
No. 57, with J. C. W., carbohydrate diet	3	18.03	2.91	*15.31	− .19	556.94	25.29	11.90	548.60	− 28.85
No. 61, with B. F. D., carbohydrate diet	1	16.52	1.64	*17.25	−2.37	341.40	15.45	12.85	436.25	−123.15
No. 62, with A. L. L., carbohydrate diet	3	16.88	2.31	15.44	− .87	455.88	21.52	12.54	465.68	− 43.86
No. 63, with A. L. L., fat diet	3	16.83	1.01	17.81	−1.99	421.43	18.03	13.48	432.81	− 42.89
Average Nos. 56, 57, 61, 62–63	13	17.52	1.98	16.30	− .75	477.04	22.34	12.66	478.41	− 36.37
Severe work experiments.										
No. 64, with A. L. L., fat diet	1	19.11	1.01	15.68	+2.42	474.94	18.03	11.70	639.27	−194.06
Average Nos. 56, 57, 61, 62, 63, 64	14	17.64	1.91	16.26	− .52	476.89	22.03	12.60	489.90	− 47.64

* Including nitrogen in perspiration also.

TABLE 69.—*Summary of average daily income and outgo of hydrogen and oxygen.*

Subject and kind of experiment.	Duration.	Hydrogen.					Oxygen.					
		(*k*) In food and drink.	(*l*) In feces.	(*m*) In urine.	(*n*) In water apparently lost.	(*o*) Gain (+) or loss (−), $k-(l+m+n)$.	(*p*) In food and drink.	(*q*) In air inhaled.	(*r*) In feces.	(*s*) In urine.	(*t*) In respiratory products.	(*u*) Gain (+) or loss (−), $(p+q)-(r+s+t)$.
Rest experiments.	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 58, with H. F., carbohydrate diet	3	125.73	4.75	44.72	80.30	− 4.04	960.94	555.54	34.21	350.35	1,117.04	+ 14.88
No. 60, with B. F. D., carbohydrate diet	3	236.53	12.64	126.21	90.65	+ 7.03	1,795.79	628.80	93.33	990.53	1,286.73	+ 54.00
Nos. 65-67, with A. L. L., carbohydrate diet	4	235.06	8.06	123.31	102.85	+ .84	1,829.69	756.27	58.77	968.68	1,463.22	+ 95.29
Average, Nos. 58, 60, 65-67	10	202.70	8.44	100.60	92.43	+ 1.23	1,558.90	657.81	61.77	789.74	1,306.42	+ 58.78
Work experiments.												
No. 56, with J. C. W., fat diet	3	628.78	25.48	125.08	439.66	+ 38.56	4,664.71	1,571.87	176.52	978.41	4,771.02	+310.63
No. 57, with J. C. W., carbohydrate diet	3	604.40	36.88	97.42	452.04	+ 18.06	4,672.67	1,576.13	277.98	758.97	5,050.59	+161.26
No. 61, with B. F. D., carbohydrate diet	1	371.16	12.53	97.68	321.09	− 60.14	2,773.62	1,309.09	88.72	763.44	3,711.74	−481.19
No. 62, with A. L. L., carbohydrate diet	3	465.03	19.72	63.07	370.13	+ 12.11	3,550.87	1,386.20	146.61	492.98	4,179.32	+118.16
No. 63, with A. L. L., fat diet	3	487.93	13.57	168.78	413.50	−107.92	3,603.08	1,439.08	91.78	1,329.05	4,435.91	−814.58
Average, Nos. 56, 57, 61, 62, 63	13	533.04	23.04	112.36	411.31	− 13.67	4,019.05	1,479.15	166.72	880.13	4,540.17	− 88.82
Severe work experiments.												
No. 64, with A. L. L., fat diet	1	825.66	13.57	123.64	664.65	+ 23.80	6,228.99	2,105.65	91.78	972.36	6,979.76	+290.74
Average, Nos. 56, 57, 61, 62, 63, 64	14	553.93	22.36	113.17	429.41	− 11.01	4,176.92	1,523.90	161.37	886.72	4,714.43	− 61.70

TABLE 70.—*Summary of average daily gain or loss of body material and ncome and outgo of energy.*

Subject and kind of experiment.	Duration.	Body material.			Energy.									
		(*a*) Protein gained (+) or lost (−).	(*b*) Fat gained (+) or lost (−).	(*c*) Carbohydrates gained (+) or lost (−).	(*d*) Of food.	(*e*) Of feces.	(*f*) Of urine.	(*g*) Of body protein gained (+) or lost (−).	(*h*) Of body fat gained (+) or lost (−).	(*i*) Of body carbohydrates gained (+) or lost (−).	(*k*) Of material actually oxidized net income $d-(e+f+g+h+i)$.	(*l*) Measured as heat. Net outgo.	(*m*) Difference between net income and net outgo.	
Rest experiments.	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Percent*
No. 58, with H. F., carbohydrate diet.....	3	−13.24	− 52.14	+ 8.82	1,500	67	76	− 75	− 497	+ 37	1,892	1,904	+ 12	+0.6
No. 60, with B. F. D., carbohydrate diet..	3	− 3.86	+ 3.81	+ 20.60	2,509	132	129	− 21	+ 36	+ 86	2,147	2,228	+ 81	+3.6
Nos. 65–67, with A. L. L., carbohydrate diet.	4	−49.58	− 87.95	+102.44	2,165	92	148	−280	− 839	+ 429	2,615	2,575	− 40	−1.6
Average, Nos. 58, 60, 65–67..........	10	−24.96	− 49.68	+ 49.80	2,069	97	121	−141	− 474	+ 208	2,258	2,270	+ 12	+ .5
Work experiments.														
No. 56, with J. C. W., fat diet............	3	+ 3.52	− 7.03	+ 5.83	5,565	309	138	+ 20	− 67	+ 24	5,141	5,284	+143	+2.7
No. 57, with J. C. W., carbohydrate diet..	3	− 1.12	− 21.48	− 26.76	5,532	268	128	− 6	− 205	− 112	5,459	5,435	− 24	− .4
No. 61, with B. F. D., carbohydrate diet..	1	−14.22	+ 9.85	−277.40	3,614	161	138	− 80	+ 94	−1,162	4,463	4,565	+102	+2.2
No. 62, with A. L. L., carbohydrate diet..	3	− 5.22	− 24.87	− 49.89	4,636	229	131	− 30	− 237	− 209	4,752	4,821	+ 69	+1.5
No. 63, with A. L. L., fat diet............	3	−11.98	− 46.69	− 2.55	4,753	210	136	− 68	− 445	− 11	4,931	4,890	− 41	− .9
Average, Nos. 56, 57, 61, 62, 63.......	13	− 4.51	− 22.34	− 39.17	5,005	247	134	− 29	− 213	− 164	5,024	5,066	+ 42	+ .8
Severe work experiment.														
No. 64, with A. L. L., fat diet............	1	+14.52	−131.26	−229.15	5,393	210	128	+ 82	−1,252	− 960	7,185	7,137	− 48	− .7
Average, Nos. 56, 57, 61, 62, 63, 64....	14	− 3.15	− 30.12	− 52.74	5,033	244	134	− 21	− 287	− 221	5,179	5,214	+ 35	+ .7

This abstract of all the data will serve to give a general impression of the factors involved in these experiments. The results show, in brief, that in most cases the nitrogen in the food eaten nearly sufficed for maintaining body equilibrium, but in some there was a decided loss of nitrogen, and in one an appreciable gain. The amount of carbon utilized was proportional to the muscular activity of the subject. The data for hydrogen as here summarized are not of special significance, as they include the hydrogen of preformed water as well as organic hydrogen. In general the output of hydrogen is parallel to that of carbon. If the oxygen eliminated in food and drink is disregarded and only the values in column *q* considered, the amount of oxygen consumed is proportional to the amount of muscular work performed. The gains or losses of body material depend upon so many conditions, such as food and muscular work, that comparison of the figures merely as given in the table would have but little significance. With regard to the energy the comparison of the material actually oxidized in the body and that of outgo is of especial interest, the percentage error being given in the last table. A more complete discussion of the factors here briefly mentioned appears in the sections that follow.

METABOLISM OF NITROGEN AND PROTEIN.

Table 71 gives the quantity of nitrogen in the food, in the feces, and in the urine, the gain or loss to the body, and for purposes of comparison the protein katabolized per person and per kilo of body weight.

TABLE 71.—*Metabolism of nitrogen and protein, metabolism experiments Nos. 56–58 and 60–67.*

Subject and kind of experiment.	Experiment No.	Duration.	Body weight.	Average daily nitrogen balance.			Gain (+) or loss (−).	Protein katabolized per day.	
				In food.	In feces.	In urine.[a]		Per person.	Per kilogram of body weight.
Rest experiments.									
		Days.	*Kgms.*	*Gms.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Grams.*
Average of 22 experiments previously reported	......	67	....	17.40	1.10	16.80	−0.50	105.00	1.54
H. F., carbohydrate diet	58	3	71.6	6.66	.40	8.47	−2.21	52.93	.74
B. F. D., carbohydrate diet	60	3	66.7	16.79	1.72	15.71	− .64	98.19	1.47
A. L. L., carbohydrate diet	65	1	72.5	15.40	.85	24.02	−9.47	150.13	2.07
A. L. L., carbohydrate diet[b]	66	1	73.0	14.11	.85	22.31	−9.05	139.44	1.91
A. L. L., carbohydrate diet[b]	67	2	72.7	11.02	.85	17.44	−7.27	109.00	1.50
Average of 27 rest experiments	......	77	....	16.72	1.08	16.61	− .97	103.81	1.52

[a] Includes outgo in perspiration when determined.
[b] Light exercise experiments.

TABLE 71.—*Metabolism of nitrogen and protein, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Subject and kind of experiment.	Experiment No.	Duration.	Body weight.	Average daily nitrogen balance.			Gain (+) or loss (−).	Protein katabolized per day.	
				In food.	In feces.	In urine.[a]		Per person.	Per kilogram of body weight.
Work experiments.									
Average of 23 work experiments previously reported	......	*Days.* 76	*Kgms.*	*Gms.* 17.30	*Gms.* 1.70	*Gms.* 17.20	*Grams.* −1.60	*Grams.* 107.50	*Grams.* 1.49
J. C. W., fat diet	56	3	75.9	18.69	1.80	16.31	+ .58	101.94	1.34
J. C. W., carbohydrate diet	57	3	76.6	18.03	2.91	15.31	− .19	95.69	1.25
B. F. D., carbohydrate diet	61	1	67.0	16.52	1.64	17.25	−2.37	107.81	1.60
A. L. L., carbohydrate diet	62	3	75.4	16.88	2.31	15.44	− .87	96.50	1.28
A. L. L., fat diet	63	3	73.4	16.83	1.01	17.81	−1.99	111.31	1.52
Average, 28 work experiments	......	89	....	17.33	1.74	17.07	−1.48	106.68	1.47
Severe work experiments.									
1 experiment previously reported	55	1	....	18.40	1.70	18.30	−1.60	114.40	1.51
A. L. L., fat diet	64	1	72.2	19.11	1.01	15.68	+2.42	98.00	1.36
Average of 2 experiments, severe work	......	2	....	18.76	1.36	16.99	+ .41	106.20	1.44
Average of 57 work and rest experiments	......	168	....	17.07	1.43	16.86	−1.22	105.36	1.49

[a] Includes outgo in perspiration when determined.

While in general we may say that persons of large body weight consume more nitrogen than those of small body weight, this observation is of no special significance here, since the diet given to the subjects was in all cases but one prescribed for the individual. In experiment No. 58, with H. F., the subject had, according to his own statements, been accustomed for many years to living on an excessively low protein diet, and consequently, in this experiment, the food contained, in compliance with his request for a small diet, but 6.66 grams of nitrogen. In the other experiments the quantity of nitrogen averaged not far from 16 grams, being somewhat smaller in the rest than in the work experiments, but, as pointed out above, it was arbitrarily established. The amounts of nitrogen in the feces varied from 0.4 to 2.91 grams, and the amount in the urine from 8.47 to 24.02 grams, both minima appearing in the urine and feces of the subject of experiment No. 58, in which the quantity of nitrogen in the food was lowest.

In all experiments save two, Nos. 56 and 64, the subjects lost nitrogen, the greatest loss appearing in Nos. 65, 66, and 67, which followed the excessive work period of No. 64, in which there was a storage of nitrogen. It would thus appear that the quantities of nitrogen furnished these individuals were not sufficient to maintain the body in nitrogen equilibrium, though, as a matter of fact, one of the other factors which influence in a marked degree the elimination of nitrogen, namely, the quantity of energy in the diet, was also deficient, so that body material was drawn upon in nearly every case. Consequently, although it is clearly shown that these subjects on the whole lost nitrogenous material, the evidence can not be taken as showing that the quantity of nitrogen would or would not have been insufficient, provided the quantity of energy in the diet had been large enough to meet the demands of the body for energy. The gain of nitrogen in experiment No. 64 and the marked loss in experiments Nos. 65, 66, and 67 are considered below.

The evidence is now rapidly accumulating regarding nitrogen metabolism, but available data do not enable us to state definitely that the quantities of nitrogen here consumed by these subjects were too small or too large for their actual needs. They were, as a matter of fact, in all cases save experiment No. 58, not far from the amounts commonly found to be consumed by individuals under similar conditions of muscular activity. Unfortunately for the purposes of discussion of the nitrogen balance, the energy of the diet was, as stated above, in most cases insufficient, and body material had to be drawn upon. It is a well-known fact that when body material is used, there is a greater consumption of protein than otherwise, and consequently the loss of body material found in these experiments does not indicate necessarily that the quantity of protein was too small with a normal maintenance amount of energy. The figures in the table are mainly of interest for purposes of comparison with earlier work, and for showing that the subjects were receiving the customary amounts of nitrogen per kilogram of body weight.

With regard to the protein katabolized per kilogram of body weight, it can be stated that it has long been known that the body can sustain itself for a considerable period of time with much smaller quantities of protein than are commonly consumed by men, and the amount of protein katabolized per kilogram of body weight is, in large measure, dependent upon the quantity of protein ingested; with a large ingestion of protein there is a large protein katabolism, and with small protein ingestion there is a greatly diminished protein katabolism. The amounts katabolized in these experiments are those commonly katabolized by subjects under like conditions of muscular activity and diet.

The data in the table, then, throw no specific light upon the absolute protein requirement, and, indeed, these experiments were not designed in any way to study this most important problem. Suffice to say that there is no evidence in the figures here presented that the amount of protein in the diet was too large for the conditions under which the subjects lived, and, as pointed out above, it is certainly unreasonable to assume that because there was a loss of body nitrogen, the quantity of protein was too small, since with the energy deficient, drafts upon body protein would normally be expected.

ERRONEOUS ASSUMPTION AS TO THE EXCRETION OF NITROGEN.

It is commonly assumed that the excretion of nitrogen through the urine is a measure of the protein katabolized in the period during which the urine is collected. Thus, an excretion of a certain amount of nitrogen in a 24-hour period from 7 a. m. to 7 a. m. is assumed to indicate that during this time there was a katabolism of a corresponding amount of protein. This assumption is open to serious error. In the first place, it is not true that all the nitrogen of food, or indeed of body material, is in the form of protein; yet by assuming that the excretion of nitrogen corresponds to the katabolism of protein, no allowance is made for the possible excretion of nitrogen in the form of creatinin, uric acid, hippuric acid, and other nitrogenous bodies, the store of which may be considerably altered in the body as a result of muscular activity, larger quantities of water, or other factors as yet but little understood. Obviously, then, the deduction that any gain of nitrogen by the body is in the form of body protein, and moreover that the quantity of nitrogen multiplied by the factor 6.0, or indeed any other constant factor, represents the total amount of protein gained, is not necessarily final. Any error in the assumption affects also the calculations of the gain or loss of fat and carbohydrates by the body, although this is much more noticeable in the case of the older methods of computation than in the new method.

Furthermore, it is conceivable that there may be a delay in the excretion of nitrogen after the katabolism of protein. In other words, there may be a marked fluctuation in the storage of the cleavage products of protein in the body. This is suggested by the figures given in Table 71. There was a noticeable increase in the nitrogen elimination in experiments Nos. 65 and 66, which were rest experiments following a day of severe muscular work, No. 64, on which there was apparently a gain of nitrogen. It is conceivable that on this day of severe muscular work there was a larger disintegration of protein material than is estimated, the disintegration products, however, not appearing in the urine until a day or two later. It is thus possible that instead of a gain of protein to the body on this particular day there was an actual katabolism of protein in the body so much greater than that estimated that there was a real loss of protein.

Until we know more definitely the nature of the decompositions of proteid material in the body and their time relations and rate of excretion, however, our only alternative seems to be to assume that the proteid disintegration corresponds to the nitrogen elimination in the urine during the given period. This is the common custom among physiologists, and in lieu of better methods, it is still adhered to in this laboratory.

ELIMINATION OF CARBON DIOXID.

Previous experimenting has shown that the elimination of carbon dioxid is in large measure, if not wholly, dependent upon muscular activity, although marked variations are noticeable with alterations in the character of the diet. It is of especial interest in discussing this problem to note that the measure of carbon dioxid as here given represents not only that eliminated through the lungs, but also the carbon dioxid of cutaneous respiration. In all forms of apparatus which rely upon breathing through tubes in the mouth or nose or masks, obviously the cutaneous respiration is eliminated, but aside from this, which is inconsequential, the amount of carbon dioxid measured in the respiration apparatus is the total quantity eliminated from the body. At present our methods of experimenting are not sufficiently refined to warrant any estimation of the small quantity of carbon dioxid dissolved in the urine.

In order to compare the periodic excretion of carbon dioxid with the output of water vapor and heat and intake of oxygen, the experiments were so adjusted that the total quantity of carbon dioxid eliminated could be determined in periods three or six hours in length. It seems clearly established that the amount of carbon dioxid eliminated per period represents very closely that actually produced during that time, there being no appreciable retention of carbon dioxid. It was formerly considered that there might be a delay in the elimination from the body of the increased carbon dioxid resulting from muscular work, but the interesting experiments of Higley and Bowen,[a] with the ingenious device designated by them as the "Chemograph," showed conclusively that the increase in the production of carbon dioxid due to muscular exertion appeared within a very few seconds after the beginning of the work. Information regarding this point had also been obtained in former experiments with the respiration calorimeter, and it was pointed out in a previous report that the data seemed to warrant the deduction that elimination of carbon dioxid follows almost immediately upon production.

The closeness with which the amount of carbon dioxid measured during any given period agrees with that produced and eliminated depends upon the extent to which the gas is retained in the chamber. The indications are that there is little if any retention, as explained below in the discussion of Table 72, showing the elimination of carbon dioxid for three, six, and twenty-four hour periods in all the experiments here reported except No. 58, in which the data were obtained only in six-hour periods.

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[a] Amer. Jour. Physiol., 12 (1904), p. 311.

TABLE 72.—*Carbon dioxid eliminated during 3-hour periods, metabolism experiments Nos. 56–58 and 60–67.*

Period.	Rest experiments.								
	Experiment No. 58,[a] with H. F., carbohydrate diet.			Experiment No. 60, with B. F. D., carbohydrate diet.			Experiments Nos. 65–67, with A. L. L., carbohydrate diet.		
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
7 a. m. to 10 a. m.	....	....	....	118.50	126.78	123.40	113.09	155.79	137.32
10 a. m. to 1 p. m.	....	....	....	97.48	116.24	105.47	86.01	138.34	120.08
Total, 6 hours	132.78	184.14	159.15	224.26	234.74	228.87	199.10	292.69	257.40
1 p. m. to 4 p. m.	....	....	....	106.95	113.70	109.74	110.49	165.39	131.74
4 p. m. to 7 p. m.	....	....	....	98.72	123.52	107.24	96.50	138.67	121.58
Total, 6 hours	179.47	206.41	190.98	205.67	237.22	216.98	206.99	297.92	253.32
Total, 12 hours	319.83	390.55	350.13	429.93	471.96	445.85	406.09	590.61	510.72
7 p. m. to 10 p. m.	....	....	....	118.83	126.88	121.77	107.18	119.88	114.26
10 p. m. to 1 a. m.	....	....	....	70.93	84.45	79.32	97.11	126.79	110.20
Total, 6 hours	168.00	171.54	169.31	197.81	204.04	201.09	213.86	246.67	224.46
1 a. m. to 4 a. m.	....	....	....	63.86	64.86	64.30	73.31	84.91	77.77
4 a. m. to 7 a. m.	....	....	....	63.77	72.85	68.72	74.30	79.19	76.65
Total, 6 hours	136.53	144.18	140.19	127.94	136.71	133.02	147.61	162.28	154.42
Total 12 hours	304.53	315.72	309.50	325.75	340.75	334.11	358.09	408.95	378.88
Total, 24 hours	628.07	706.27	659.63	761.43	807.78	779.96	815.04	952.08	889.60

Period.	Work experiments.						
	Experiment No. 56,[b] with G. C. W., fat diet.			Experiment No. 57, with G. C. W., carbohydrate diet.			Experiment No. 61,[c] with B. F. D., carbohydrate diet.
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams,*
7 a. m. to 10 a. m.	[d] 343.56	[d] 344.00	[d] 343.78	331.40	418.34	378.88	363.72
10 a. m. to 1 p. m.	[d] 274.20	[d] 410.72	[d] 342.46	391.94	490.83	449.40	396.51
Total 6 hours	618.20	754.28	688.73	723.34	909.17	828.28	760.23
1 p. m. to 4 p. m.	[d] 360.62	[d] 368.19	[d] 364.41	342.51	397.16	367.40	267.44
4 p. m. to 7 p. m.	[d] 293.56	[d] 315.92	[d] 304.74	201.41	439.07	354.21	211.13
Total 6 hours	654.18	684.11	673.05	598.57	784.69	721.61	478.57
Total 12 hours	1,302.31	1,408.46	1,361.78	1,507.74	1,633.92	1,549.89	1,238.80
7 p. m. to 10 p. m.	[d] 129.56	[d] 136.14	[d] 132.85	165.17	166.58	166.08	117.96
10 p. m. to 1 a. m.	[d] 103.22	[d] 103.48	[d] 103.35	104.70	139.68	120.10	89.72
Total 6 hours	232.78	239.62	236.72	271.20	306.26	286.18	207.68
1 a. m. to 4 a. m.	[d] 87.19	[d] 88.31	[d] 87.75	84.63	87.68	86.19	82.54
4 a. m. to 7 a. m.	[d] 74.01	[d] 78.29	[d] 76.15	87.82	90.21	89.30	70.61
Total 6 hours	162.32	165.48	163.69	174.07	177.89	175.49	153.15
Total 12 hours	395.10	405.10	400.41	445.27	480.77	461.67	360.83
Total 24 hours	1,697.41	1,813.56	1,762.19	1,953.01	2,092.88	2,011.56	1,599.63

[a] During this experiment records were made only by 6-hour periods.
[b] During first day of this experiment record was made only by 6-hour periods.
[c] One day experiment.
[d] Second and third days.

Table 72.—*Carbon dioxid eliminated during 3-hour periods, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Period.	Work experiments—Continued.						Severe work experiment No. 64, with A. L. L., fat diet.
	Experiment No. 62, with A. L. L., carbohydrate diet.			Experiment No. 63, with A. L. L., fat diet.			
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
7 a. m. to 10 a. m	330.81	342.30	336.88	307.30	329.29	319.34	368.49
10 a. m. to 1 p. m	311.66	332.90	323.79	287.33	303.21	297.27	304.66
Total 6 hours	649.17	675.20	660.67	594.63	630.55	616.61	673.15
1 p. m. to 4 p. m	319.61	335.88	325.93	301.20	322.12	314.88	392.07
4 p. m. to 7 p. m	292.34	323.74	310.27	256.48	263.28	260.86	336.41
Total 6 hours	628.22	643.35	636.20	564.48	584.15	575.74	728.48
Total 12 hours	1,285.85	1,312.24	1,296.87	1,178.78	1,209.15	1,192.35	1,401.63
7 p. m. to 10 p. m	113.93	150.77	134.54	122.19	124.77	123.58	384.07
10 p. m. to 1 a. m	93.01	114.48	105.10	104.00	109.78	106.98	249.68
Total 6 hours	228.41	246.72	239.64	226.19	233.55	230.56	633.75
1 a. m. to 4 a. m	81.83	94.39	87.35	70.17	86.51	80.13	223.44
4 a. m. to 7 a. m	80.62	86.55	83.60	81.21	88.02	83.96	85.19
Total 6 hours	165.46	175.01	170.95	158.19	167.72	164.09	308.63
Total 12 hours	403.42	416.17	410.59	391.74	399.65	394.65	942.38
Total 24 hours	1,695.94	1,724.42	1,707.46	1,578.43	1,601.69	1,587.00	2,344.01

The influence of the character of the diet on carbon dioxid excretion is not apparent in the rest experiments, since all the subjects partook of a diet which was largely carbohydrate in nature. The figures for minimum and maximum represent practically the results of three days of experimenting in the case of experiments Nos. 58 and 60, and of four days experimenting with Nos. 65–67. As would be expected, during the last half of the night, namely, from 1 a. m. to 7 a. m., the output remained quite constant for each individual. On comparing the work experiments, it is seen that with the carbohydrate diet there was a larger output of carbon dioxid than with the fat diet. This is more clearly established in the case of experiments Nos. 62 and 63, in which the total amount of external muscular work was uniform, than in experiments Nos. 56 and 57, in which there were small variations in the amounts of muscular work. In both series, however, the results show the increased carbon dioxid output with the carbohydrate diet.

In the work experiments the constancy of output during the night period from 1 a. m. to 7 a. m. is again very noticeable. Obviously the severe work experiment, where the daily programme was entirely different from any others, and where a considerable proportion of muscular work was performed during the night, can not be compared with the other days. It is interesting to note that there was an enormous output of carbon dioxid—2,344 grams on this day of severe muscular work. It is furthermore significant that in the period in experiment No. 64 when the subject was sleeping, the output of carbon dioxid was practically the same as that of experiments Nos. 62 and 63 during a corresponding period, although in the former case the period had been preceded by one of severe muscular work, in which over 200 grams of carbon dioxid had been eliminated, whereas only about 80 grams had been eliminated during the sleeping period from 1 a. m. to 4 a. m., of experiments Nos. 62 and 63. This is of itself a marked indication of the absence of any material retention of carbon dioxid in the chamber after muscular work.

CARBON DIOXID ELIMINATION PER HOUR.

The fact that the amount of carbon dioxid eliminated is directly influenced by muscular work is more clearly brought out when the rates per hour for the different periods of the day are computed. The average amounts of the carbon dioxid eliminated by lungs and skin per day and rates in proportion for the different periods are given in Table 73. The experiments are again subdivided into rest, work, and severe work, and the character of the diet is also indicated.

TABLE 73.—*Carbon dioxid eliminated by lungs and skin—Average amounts per day and rates and proportions for different periods.*

Subject and kind of experiment.	Duration.	Total amounts in 24 hours.	Rates per hour.					Proportion of total for 24 hours.			
			Day periods.		Night periods.		Average for 24 hours.	Day periods.		Night periods.	
			7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.		7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.
Rest experiments.											
	Days.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
No. 58, H. F., carbohydrate diet	3	659. 63	26. 52	31. 83	28. 22	23. 37	27. 48	24. 1	28. 9	25. 7	21. 3
No. 60, B. F. D., carbohydrate diet	3	779. 96	38. 15	36. 16	33. 52	22. 17	32. 50	29. 4	27. 8	25. 8	17. 0
Nos. 65–67, A. L. L., carbohydrate diet	4	889. 60	42. 90	42. 22	37. 41	25. 74	37. 07	23. 9	28. 5	25. 2	17. 4
Average of rest experiments	10	787. 72	36. 56	37. 29	33. 48	23. 96	32. 82	27. 9	28. 4	25. 5	18. 2
Work experiments.											
No. 56, J. C. W., carbohydrate diet	3	1,762. 19	114. 79	112. 18	39. 45	27. 28	73. 42	39. 1	38. 2	13. 4	9. 3
No. 57, J. C. W., fat diet	3	2,011. 56	138. 05	120. 27	47. 70	29. 25	83. 82	41. 2	35. 9	14. 2	8. 7
No. 61, B. F. D., carbohydrate diet	1	1,599. 63	126. 71	79. 76	34. 61	25. 53	66. 65	47. 5	29. 9	13. 0	9. 6
No. 62, A. L. L., carbodyhrate diet	3	1,707. 46	110. 11	106. 03	39. 94	28. 49	71. 14	38. 7	37. 3	14. 0	10. 0
No. 63, A. L. L., fat diet	3	1,587. 00	102. 77	95. 96	38. 43	27. 35	66. 13	38. 9	36. 3	14. 5	10. 3
Average of work experiments	13	1,754. 17	117. 22	106. 39	40. 86	27. 90	73. 09	40. 1	36. 4	14. 0	9. 5
No. 64, A. L. L., fat diet, severe work	1	2,344. 01	112. 19	121. 41	105. 63	51. 44	97. 67	28. 7	31. 1	27. 0	13. 2
Average of work and severe work experiments	14	1,796. 31	116. 86	107. 46	45. 49	29. 58	74. 85	39. 0	35. 9	15. 2	9. 9

The average results show that during the rest experiments about 37 grams of carbon dioxid were eliminated per hour from 7 a. m. to 7 p. m. For the period from 7 p. m. to 1 a. m. the output is somewhat lower, owing to the fact that the subject usually retires at 11 p. m., and hence the muscular activity is markedly diminished. The average output during this period was 33.48 grams, while in the period from 1 a. m. to 7 a. m., during which time the subject is at rest and usually asleep and the muscular activity is least, the carbon dioxid was similarly lower than at any other period of the day, the average output during this period being not far from 24 grams. The average of the ten days of the experiments here reported for the twenty-four hours is 32.82 grams. It should be noted, however, that because of experiment No. 58, in which the subject's routine was such as to include a large amount of rest, the average for the rest experiments is considerably lowered. Experiments Nos. 60 and 65–67 are much more in accord with the results of 14 experiments previously published.[a] It is significant, however, that when the muscular activity was alike in all experiments, namely, from 1 a. m. to 7 a. m., the discrepancy between the three experiments practically disappeared.

During the work experiments the output is in large measure proportional to the amount of work done, although, as has been pointed out before, the influence of the character of the diet must not be overlooked. Since the work in all the experiments except No. 64 was performed between 7 a. m. and 7 p. m., the greatest differences between the rest and work experiments are found during these hours. During the evening period, from 7 p. m. to 1 a. m., there was on the average a larger excretion of carbon dioxid during the work days than during the rest days, and at first sight this might seem to be an indication that there was a lag of the carbon dioxid elimination after work. Six of the thirteen days of the work experiments, however, were made with the subject J. C. W., who was a much larger man than the others, and if these two experiments, Nos. 56 and 57, are eliminated, the average for the evening period is not far from that for experiments Nos. 60 and 65–67. As a matter of fact, there is also somewhat more external muscular exertion in the period from 7 p. m. to 1 a. m. during work experiments than during rest experiments. There is more furniture to adjust, a larger collection of dishes to be passed out of the food aperture, the preparation for retiring is somewhat more complicated, and hence it is not at all surprising that there is a slightly greater elimination of carbon dioxid than during the same period in the rest experiments.

In the night period, from 1 a. m. to 7 a. m., there is again a slight increase over the period in rest experiments. The comparison in this case is by no means a satisfactory one, since there is no work experiment with H. F.; and with B. F. D. there is only one day of work. This leaves for comparison only the experiments with A. L. L. In his case the average from 1 a. m. to 7 a. m. during rest was 25.74, and during work practically 28 grams, a slight increase. It is difficult to state exactly what this increase represents. It may possibly be explained by the fact that, contrary to what might be expected, the subjects did not as a rule sleep as well on the nights after work as they did on the nights after rest. This has been a matter of common observation in all the experiments made thus far.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 132.

The proportion of the total carbon dioxid eliminated in the different periods of the day is given in the last four columns of the table. These figures show that during rest experiments about 28 per cent of the total is eliminated during the period from 7 a. m. to 1 p. m., a similar proportion from 1 p. m. to 7 p. m., a slightly smaller proportion from 7 p. m. to 1 a. m., and but 18.2 per cent from 1 a. m. to 7 a. m. With the introduction of muscular work in the experiments these proportions are very materially altered, and the amount eliminated between 1 a. m. and 7 a. m. may fall to as low as 8.7 per cent of the total. The percentage elimination during the work experiments is, in fact, almost directly proportional to the degree of activity.

ELIMINATION OF WATER.

The discussion of the elimination of water is rendered somewhat unsatisfactory by the fact that a very large proportion of the water in the body is taken in as the preformed water of food and drink, and another portion is formed from the combustion of organic hydrogen in the body. It is not possible to determine what proportions of the amounts eliminated during any given period are derived from these two sources, consequently any discussion of the elimination must include not only the preformed water of food and drink, but also that resulting from the oxidation of organic hydrogen. In Table 74 data for the income and outgo of water in the metabolism experiments here reported are given.

TABLE 74.—*Daily income and outgo of water in metabolism experiments Nos. 56–58 and 60–67.*

Subject and kind of experiment.	Duration.	Income.			Outgo.			
		In food.	In drink.	Total.	In feces.	In urine.	In respiration and perspiration.	Total.
Rest experiments.								
No. 58., with H. F., carbohydrate diet:	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Minimum	3	536.80	263.00	882.30	34.77	366.90	507.13	914.80
Maximum		619.30	400.00	958.50	34.77	410.00	828.78	1,261.71
Average	......	571.53	354.33	925.87	34.77	383.27	717.62	1,135.65
No. 60, with B. F. D., carbohydrate diet:								
Minimum	3	1,054.80	700.00	1,754.80	97.07	951.30	272.15	1,320.52
Maximum		1,159.30	700.00	1,859.30	97.07	1,298.88	1,198.69	2,594.64
Average	......	1,089.63	700.00	1,789.63	97.07	1,098.83	810.13	2,006.03
No. 65, with A. L. L., carbohydrate diet	1	2,255.51	....	2,255.51	62.17	1,020.64	1,072.46	2,155.27
No. 66, with A. L. L., carbohydrate diet	1	2,039.22	....	2,039.22	62.17	981.18	883.83	1,927.18
No. 67, with A. L. L., carbohydrate diet:								
Minimum	2	1,405.02	....	1,405.02	62.17	1,013.77	842.28	1,918.22
Maximum		1,581.24	....	1,581.24	62.17	1,266.29	877.76	2,206.22
Average	......	1,493.13	....	1,493.13	62.17	1,140.03	860.02	2,062.22
Average, Nos. 65, 66, and 67	4	1,820.25	....	1,820.25	62.17	1,070.47	919.08	2,051.72
Average, Nos. 58, 60, 65, 66, and 67	10	1,226.45	[a] 527.17	1,542.75	64.42	872.82	825.96	1,763.19
Work experiments.								
No. 56, with J. C. W., fat diet:								
Minimum	3	2,935.50	1,950.00	4,885.50	191.30	914.30	3,702.27	5,012.74
Maximum		3,011.70	1,950.00	4,961.70	191.30	1,425.80	4,179.78	5,319.37
Average	......	2,972.43	1,950.00	4,922.43	191.30	1,089.20	3,929.73	5,210.23
No. 57, with J. C. W., carbohydrate diet:								
Minimum	3	2,310.10	2,291.00	4,601.10	298.53	789.10	3,894.76	5,125.50
Maximum		2,394.70	2,291.00	4,685.70	298.53	932.21	4,191.47	5,279.10
Average	......	2,366.50	2,291.00	4,657.50	298.53	842.61	4,039.67	5,180.81
No. 61, with B. F. D., carbohydrate diet	1	1,029.50	1,834.00	2,863.50	92.67	843.00	2,869.45	3,805.12
No. 62, with A. L. L., carbohydrate diet:								
Minimum	3	591.10	2,797.90	3,491.10	151.60	490.50	2,933.95	3,579.85
Maximum		779.40	2,900.00	3,577.30	151.60	626.70	3,573.19	4,351.49
Average	......	681.53	2,859.00	3,540.53	151.60	537.17	3,307.66	3,996.43
No. 63, with A. L. L., fat diet:								
Minimum	3	629.50	1,731.80	3,108.10	97.15	913,45	3,479.03	4,963.29
Maximum		2,420.10	2,478.60	4,151.90	97.15	1,758.86	3,952.69	5,508.15
Average	......	1,666.40	2,137.03	3,803.43	97.15	1,476.45	3,695.23	5,268.83
Average, Nos. 56, 57, 61, 62, and 63	13	[a]1,853.08	2,272.70	4,125.78	177.57	975.33	3,675.87	4,828.77
Severe work experiment.								
No. 64, with A. L. L., fat diet	1	2,897.50	3,832.00	6,729.50	97.15	1,075.55	5,939.67	7,112.37
Average, Nos. 56, 57, 61, 62, 63, and 64	14	[a]1,927.68	2,384.08	4,311.76	171.83	982.49	3,837.57	4,991.88

[a] Average for 2 experiments.

The quantity of water in the food depends largely upon the nature of the diet and, indeed, to a considerable extent upon the quantity of milk consumed, milk being used in these experiments as food rather than as drink. The quantity of drinking water was quite small in the rest experiments; in fact, in those in which there was a large quantity of water in the food no drinking water was taken. The quantity in the feces was small; that in the urine was much larger, but fluctuated within very wide limits, being dependent upon the amounts taken in the food and drink and those eliminated by the lungs and skin. The quantity of water of respiration and perspiration is determined in large measure by the muscular activity and by the degree of humidity of the air in the respiration chamber. This is discussed in detail in the section on ventilation. (See p. 237.) In the work experiments, in general, the quantity of water in both food and drink was very much larger, though in experiment No. 62 the amount of water in the food was unusually small. In experiment No. 64, with severe muscular work, the total amount was especially large. The larger amount in the feces in work experiments was due to the increase in amount of feces resulting from the larger diet consumed. It is interesting to note that in experiments Nos. 56 and 57 with J. C. W., and also in Nos. 62 and 63 with A. L. L., the amount of water in the feces from a carbohydrate diet was considerably greater than in that from a fat diet. When the largely increased amounts of drinking water are taken into consideration, it is somewhat surprising that larger fluctuations in the volume of urine were not found. On the average, the quantity of water in the urine was but very little less in the rest than in the work experiments. The increased output of water in work experiments, which was very large, was of course mainly that of respiration and perspiration. In experiment No. 64 the total water output is nearly double that in experiments Nos. 62 and 63. The amount of water thus eliminated is therefore approximately proportional to the amount of work done.

WATER OF RESPIRATION AND PERSPIRATION.

It has been explained (p. 63) that the output of water from the lungs and skin is determined from the data regarding the quantity of water leaving the chamber in the ventilating air current and that condensed on the absorbers and collected in the drip cups. To this is added in work experiments the amount collected in the underclothes from day to day, but during rest experiments the variations in the weight of the underclothes are so slight as to make this hardly necessary. The elimination of water from the lungs and skin during the 3-hour periods in the rest and work experiments is given in detail in Table 112 of the Appendix, and summarized in Table 75.

Table 75.—*Water eliminated from lungs and skin, during 3-hour periods, in metabolism experiments Nos. 56–58 and 60–67.*

Period.	Rest experiments.								
	Experiment No. 58, with H. F., carbohydrate diet.[a]			Experiment No. 60, with B. F. D., carbohydrate diet.			Experiments Nos. 65–67, with A. L. L., carbohydrate diet.		
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
7 a. m. to 10 a. m.	......	......	......	37.52	171.06	114.49	109.39	142.65	123.66
10 a. m. to 1 p. m	......	......	......	16.66	162.64	98.95	107.03	130.20	117.43
Total, 6 hours	122.62	214.55	172.26	54.18	333.68	213.44	216.42	272.85	241.09
1 p. m. to 4 p. m	......	......	......	32.06	169.84	108.76	103.23	136.81	115.02
4 p. m. to 7 p. m	......	......	......	45.59	169.25	111.88	105.89	128.01	112.32
Total, 6 hours	111.02	213.41	171.52	77.65	339.09	220.64	209.87	264.82	227.34
Total, 12 hours	233.64	404.67	343.78	131.83	672.77	434.08	426.29	535.67	468.43
7 p. m. to 10 p. m	......	......	......	38.95	148.66	105.49	99.74	140.76	113.49
10 p. m. to 1 a. m	......	......	......	40.86	141.24	98.66	109.76	142.48	119.37
Total, 6 hours	129.73	226.68	190.17	79.81	289.90	204.15	213.20	283.24	232.86
1 a. m. to 4 a. m.	......	......	......	31.21	121.88	85.88	106.86	130.11	114.39
4 a. m. to 7 a. m.	......	......	......	29.30	114.61	86.02	94.94	121.44	103.40
Total, 6 hours	143.76	209.08	183.67	60.51	236.02	171.90	202.79	251.55	217.79
Total, 12 hours	273.49	435.76	373.84	140.32	525.92	376.05	415.99	534.79	450.66
Total, 1 day	507.13	828.78	717.62	272.15	1,198.69	810.13	842.28	1,072.46	919.08

Period.	Work experiments.						
	Experiment No. 56, with J. C. W., fat diet.[b]			Experiment No. 57, with J. C. W., carbohydrate diet.			Experiment No. 61, with B. F. D., carbohydrate diet.
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
7 a. m. to 10 a. m.	740.51	887.24	813.88	756.44	952.67	855.66	543.97
10 a. m. to 1 p. m.	745.48	844.17	814.82	834.03	1,054.63	932.56	557.01
Total, 6 hours	1,342.35	1,771.41	1,533.25	1,590.47	2,007.30	1,788.22	1,100.98
1 p. m to 4 p.m	833.64	849.46	841.55	621.71	872.30	741.79	565.26
4 p. m. to 7 p. m	831.39	850.37	840.88	666.10	889.66	769.31	553.50
Total, 6 hours	1,553.48	1,699.83	1,639.45	1,287.81	1,761.96	1,511.10	1,118.76
Total, 12 hours	2,895.83	3,436.44	3,172.70	3,250.41	3,352.43	3,299.32	2,219.74
7 p. m. to 10 p. m	178.06	188.05	183.06	184.64	215.19	197.40	177.82
10 p. m. to 1 a. m	189.18	191.53	190.35	151.14	216.40	188.30	164.62
Total, 6 hours	369.59	418.03	388.28	343.52	431.59	385.70	342.44
1 a. m. to 4 a. m	179.90	191.81	185.86	151.13	212.06	178.14	159.63
4 a. m. to 7 a. m	171.83	174.30	173.06	149.70	195.39	176.51	147.64
Total, 6 hours	351.73	388.41	368.75	300.83	407.45	354.65	307.27
Total, 12 hours	721.32	806.44	757.03	644.35	839.04	740.35	649.71
Total 1 day	3,702.27	4,179.78	3,929.73	3,894.76	4,191.47	4,039.67	2,869.45

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[a] Determined for 6-hour periods only.

[b] During the first day of experiment No. 56 records were made only by 6-hour periods. The figures for "total 6 hours" therefore represent the data for all 3 days, while the figures for individual 3-hour periods represent only the second and third days of the experiment.

Table 75.—*Water eliminated from lungs and skin, during 3-hour periods, in metabolism experiments Nos. 56–58 and 60–67*—Continued.

Period.	Work experiments—Continued.						Severe work experiment No. 64, with A. L. L., fat diet.
	Experiment No. 62, with A. L. L., carbohydrate diet.			Experiment No. 63, with A. L. L., fat diet.			
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
7 a. m to 10 a.m	587.68	764.62	681.36	719.41	825.58	769.05	830.23
10 a. m. to 1 p. m	591.46	751.41	679.13	705.06	829.77	764.65	816.02
Total, 6 hours	1,179.14	1,516.03	1,360.49	1,424.47	1,655.35	1,533.70	1,646.25
1 p. m. to 4 p. m	573.70	752.64	673.91	714.52	826.70	771.30	828.70
4 p. m. to 7 p. m	586.39	755.58	683.30	713.77	833.59	769.52	816.91
Total, 6 hours	1,160.09	1,508.22	1,357.21	1,428.29	1,660.29	1,540.82	1,645.61
Total, 12 hours	2,339.23	3,024.25	2,717.71	2,852.76	3,315.64	3,074.52	3,291.86
7 p. m. to 10 p. m	132.47	152.62	141.85	155.79	157.99	156.33	838.48
10 p. m. to 1 a. m	140.75	171.83	158.33	162.06	163.89	163.25	826.32
Total, 6 hours	273.22	315.02	300.18	317.85	321.88	319.58	1,664.80
1 a. m. to 4 a.m	134.26	157.18	145.14	128.65	157.82	146.64	816.91
4 a. to 7 a. m	135.73	156.74	144.64	148.26	160.22	154.48	166.10
Total, 6 hours	275.72	313.92	289.78	276.91	318.04	301.12	983.01
Total, 12 hours	548.94	626.20	589.95	598.79	637.05	620.70	2,647.81
Total, 1 day	2,933.95	3,573.19	3,307.66	3,479.03	3,952.69	3,695.22	5,939.67

The results are tabulated by 3, 6, 12, and 24 hour periods, thus enabling comparison with the carbon output previously given, and also with the oxygen consumption and heat elimination as given beyond. It is important to bear in mind that these results do not include the water of feces and urine. In experiment No. 58 the water elimination per day varied from 507 to 828 grams, the difference being due in large measure to variations in the degree of activity. In experiment No. 60 there were still greater variations in the elimination of water, ranging from 272 to 1,198 grams. These large fluctuations were unquestionably due to the peculiar conditions of ventilation which obtained during the first and second day of this experiment. It will be recalled that on the first day the subject wore a mask which immediately withdrew from in front of the face all the air leaving the lungs; and on the second day the ventilation was purposely cut down to such an extent that the carbon dioxid and water vapor accumulated very materially. In both of these experiments, then, the conditions for the individual days were so lacking in uniformity that variations in water elimination day by day are to be expected. In experiments Nos. 65–67, on the other hand, the daily conditions were more uniform, and the variations for the total day ranged from 842 to 1,072 grams, which are not at all considerable when compared with those in the other experiments. Likewise, when compared with a series of rest experiments with the subject of J. C. W., previously published,[a] these variations are found to be about what would be expected.

During the day periods, under ordinary conditions, the water elimination is in general proportional to the time. In other words, for every six hours there is an elimination of water during rest experiments which is practically constant. This is best shown in the columns of averages. For example, in experiment No. 58, during the four 6-hour periods covering the entire day, the elimination of water was 172, 171, 190, and 183 grams, and in experiments Nos. 65–67, where the conditions were even more comparable, the elimination for the four 6-hour periods was 241, 227, 232, and 217 grams. These data and those for similar experiments previously published indicate that the elimination of water during rest experiments is a fairly constant factor, the amount varying with the individual. In these experiments it ranged from approximately 180 grams per 6 hours with subject H. F. to 230 grams with subject A. L. L.

During the work experiments the elimination of water is affected very markedly by the work done, and it is difficult to draw any definite conclusions regarding the different subjects. With experiments Nos. 56 and 57, in which the work was approximately uniform, although there were differences in the diet, the average elimination of water from the lungs and skin was practically the same each day, and the averages by 3-hour periods are not at all unlike. On the contrary, with the subject B. F. D. there was a markedly smaller elimination of water during the work experiments than in either Nos. 56 or 57, although it should be considered that the work performed also was considerably less.

In experiments Nos. 62 and 63 with A. L. L. on different diets and uniform activity the elimination of water was slightly greater with the fat diet than with the carbohydrate diet. This increase obtains throughout the average for the periods as well as for the whole day. In the severe work experiments the quantity of water eliminated was very much greater than with the others, but here again there is a surprising constancy in the agreement of the different 6-hour periods, and, indeed, of the 3-hour periods.

WATER OF RESPIRATION AND PERSPIRATION PER HOUR.

The regularity in the elimination of water through the lungs and skin in rest experiments during the different periods of the day is much more strikingly shown when the rates per hour are computed and the proportions of the total water elimination for the different periods are given. These data for both rest and work experiments are shown in Table 76.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 135.

TABLE 76.—*Water eliminated by lungs and skin— Average amounts per day and rates and proportions for different periods.*

Subject and kind of experiment.	Duration.	Total amounts in 24 hours.	Rates per hour.					Proportions of total for 24 hours.			
			Day periods.		Night periods.		Average for 24 hours.	Day periods.		Night periods.	
			7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.		7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.
Rest experiments.											
	Days.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
No. 58, H. F., carbohydrate diet	3	717.62	28.71	28.59	31.69	30.61	29.90	24.0	23.9	26.5	25.6
No. 60, B. F. D., carbohydrate diet	3	810.13	35.57	36.77	34.03	28.65	33.76	26.4	27.2	25.2	21.2
Nos. 65-67, A. L. L., carbohydrate diet	4	919.08	40.18	37.89	38.81	36.30	38.30	26.2	24.8	25.3	23.7
Average of rest experiments	10	825.96	35.36	34.76	35.24	32.30	34.42	25.7	25.2	25.6	23.5
Work experiments.											
No. 56, J. C. W., carbohydrate diet	3	3,929.73	255.54	273.24	64.71	61.46	163.74	39.0	41.7	9.9	9.4
No. 57, J. C. W., fat diet	3	4,039.67	298.04	251.85	64.28	59.11	168.32	44.3	37.4	9.5	8.8
No. 61, B. F. D., carbohydrate diet	1	2,869.45	183.50	186.46	57.07	51.21	119.56	38.4	39.0	11.9	10.7
No. 62, A. L. L., carbohydrate diet	3	3,307.66	226.75	226.20	50.03	48.30	137.82	41.1	41.0	9.1	8.8
No. 63, A. L. L., fat diet	3	3,695.22	255.62	256.80	53.26	50.19	153.97	41.5	41.7	8.6	8.2
Average of work experiments	13	3,675.87	253.18	246.98	57.99	54.49	153.16	41.3	40.3	9.5	8.9
No. 64, A. L. L., fat diet, severe work	1	5,939.67	274.38	274.27	277.47	163.84	247.49	27.7	27.7	28.0	16.6
Average of all work experiments	14	3,837.57	254.69	248.93	73.67	62.30	159.90	39.8	38.9	11.5	9.8

From the above table it is seen that in the rest experiments for the same subject the rates per hour were very nearly constant, and consequently the proportion of the total water elimination in the different periods similarly constant. The regularity is such that on the average of the ten days of rest experiments the water eliminated for each six hours was very close to 25 per cent of the total. It is interesting to note that the widest discrepancy noted in any case is in the period from 1 a. m. to 7 a. m. of experiment No. 60, as compared with that from 1 p. m. to 7 p. m., where the difference is 6 per cent. The detailed data for this experiment, given in the Appendix, show that the ventilation conditions during this experiment are such as to render it distinctly abnormal for purposes of comparison such as this, though even with the abnormal ventilation the percentage of water eliminated during this period was very close to the average during rest experiments under normal conditions.

In work experiments the rates per three-hour period are seen to be much greater during the performance of muscular work. The gains in weight of the heat-absorbing system and the absorption of water in the underclothing are important factors in the determination of the elimination by periods. The gain in weight of the underclothing was ascertained but once for each day. As previously explained, when the work for the day was over a clean suit of underclothing was put on and the suit which had been worn was sent out from the chamber to be weighed. It was assumed that the gain in weight should be apportioned equally among the several work periods, and accordingly it was so divided. In the earlier experiments the change in weight of the absorbers was ascertained by weighing once every six hours. It was then assumed for purposes of comparison that the gain or loss was due equally to each of the two three-hour periods. In the later work experiments the absorbers were weighed less frequently, but the same method of apportionment was followed. Since the total elimination of water per three-hour period depends so largely upon the correctness of these assumptions, no definite conclusions seem warranted, though there is no reason to believe that any large error is thereby introduced. Obviously, any possible error for one period is counterbalanced by some other during the day, and the total figures for each day, and therefore for each experiment as a whole, are correct.

The same fluctuations observed in the rates per hour are also noticeable in the percentages for the different periods. In experiment No. 57 the proportion fell as low as 8.8 per cent during the period from 1 a. m. to 7 a. m., and rose as high as 44.3 per cent in the period from 7 a. m. to 1 p. m. This computation is of course entirely dependent on the accuracy of the assumption as to the apportionment of the water collected on the heat absorbers and in the underclothing.

It should be clearly understood that the elimination of water per hour is but indirectly connected with the oxidation of organic hydrogen; consequently no deductions can be drawn from these data regarding the elimination of water formed from the oxidation of the hydrogen of the molecule of protein or fat. The hydrogen and oxygen of the carbohydrate molecule can, for purposes of discussion, be considered as preformed water.

CONSUMPTION OF OXYGEN.

In all previously reported experiments made in this laboratory no direct determinations of oxygen were possible, though recourse was had to the method described by Rosa[a] for estimating the amount of oxygen consumed. In the experiments here reported oxygen determinations were made by periods, the same as those for which the carbon dioxid and water vapor were measured. The data regarding the determinations of oxygen in the whole series of experiments, by three, six, twelve, and twenty-four hour periods, except for the first day of experiment No. 56 and the whole of experiment No. 58, in which the determinations were not made for three-hour periods, are given in detail in Table 115 of the Appendix, and here summarized in Table 77.

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[a] Phys. Rev., 10 (1900), p. 129.

TABLE 77.—*Oxygen consumed by subjects in 3-hour periods, metabolism experiments Nos. 56–58 and 60–67.*

Period.	Rest experiments.								
	Experiment No. 58, with H. F., carbohydrate diet.[a]			Experiment No. 60, with B. F. D., carbohydrate diet.			Experiment Nos. 65–67, with A. L. L., carbohydrate diet.		
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
7 a. m. to 10 a. m	....	....	....	97.58	113.79	107.26	107.49	137.53	122.72
10 a. m. to 1 p. m	....	....	....	73.62	91.14	82.94	76.12	118.31	103.57
Total, 6 hours	121.70	157.23	144.83	148.04	197.85	190.20	183.61	255.01	226.29
1 p. m. to 4 p. m	....	....	....	88.33	90.70	89.84	95.14	139.73	111.28
4 p. m. to 7 p. m	....	....	....	76.79	89.97	82.26	84.50	118.20	99.89
Total, 6 hours	135.42	153.59	147.48	165.12	180.64	172.09	185.12	242.81	211.17
Total, 12 hours	272.13	313.82	292.31	349.16	369.39	362.31	368.73	497.82	437.45
7 p. m. to 10 p. m	....	....	....	93.44	99.32	97.00	87.39	113.30	95.80
10 p. m. to 1 a. m	....	....	....	52.11	58.71	55.48	65.58	104.69	84.87
Total, 6 hours	138.25	146.71	141.12	149.06	156.95	152.48	152.97	217.99	180.67
1 a. m. to 4 a. m	....	....	....	52.46	57.34	54.27	68.67	80.11	73.29
4 a. m. to 7 a. m	....	....	....	54.45	64.84	59.74	61.85	68.22	64.85
Total, 6 hours	118.12	128.60	122.10	107.47	117.30	114.01	130.57	147.55	138.15
Total, 12 hours	256.37	273.31	263.22	258.90	274.25	266.49	300.05	360.43	318.81
Total, 24 hours	528.50	589.13	555.54	623.41	635.72	628.80	707.00	797.87	756.27

Period.	Work experiments.						
	Experiment No. 56,[b] with J. C. W., fat diet.			Experiment No. 57, with J. C. W., carbohydrate diet.			Experiment No. 61, with B. F. D., carbohydrate diet.
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
7 a. m. to 10 a. m	301.51	342.13	321.82	241.51	300.82	277.66	266.42
10 a. m. to 1 p. m	250.88	360.15	305.52	291.86	410.63	352.78	333.77
Total, 6 hours	552.39	702.28	613.02	533.37	711.45	630.44	600.19
1 p. m. to 4 p. m	313.78	332.64	323.21	252.83	355.94	298.31	220.04
4 p. m. to 7 p. m	251.87	288.99	270.43	160.18	335.63	272.67	172.85
Total, 6 hours	584.51	602.77	596.63	516.12	608.35	570.98	392.89
Total, 12 hours	1,155.16	1,286.79	1,209.64	1,121.83	1,254.86	1,201.42	993.08
7 p. m. to 10 p. m	110.12	122.22	116.67	106.90	123.32	114.70	107.03
10 p. m. to 1 a. m	91.93	106.08	99.01	85.73	88.72	87.43	74.34
Total, 6 hours	204.54	216.20	211.63	192.63	211.15	202.13	181.37
1 a. m. to 4 a. m	80.89	81.63	81.26	66.48	160.58	105.42	72.21
4 a. m. to 7 a. m	64.81	70.73	67.77	62.10	70.11	67.16	62.43
Total, 6 hours	146.44	153.71	150.59	136.59	229.85	172.58	134.64
Total, 12 hours	358.25	365.77	362.22	329.22	441.00	374.71	316.01
Total, 24 hours	1,517.80	1,652.56	1,571.87	1,556.79	1,608.76	1,576.13	1,319.09

[a] During this experiment records were made only by 6-hour periods.
[b] During the first day of this experiment records were made only by 6-hour periods.

TABLE 77.—*Oxygen consumed by subjects in 3-hour periods, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Period.	Work experiments—Continued.						Severe work experiment No. 64, with A. L. L., fat diet.[a]
	Experiment No. 62, with A. L. L., carbohydrate diet.			Experiment No. 63, with A. L. L., fat diet.			
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
7 a. m. to 10 a. m	267. 16	284. 58	275. 24	278. 06	291. 52	285. 33	338. 31
10 a. m. to 1 p. m	253. 08	260. 41	256. 01	251. 84	265. 26	259. 12	270. 66
Total, 6 hours	521. 71	537. 66	531. 25	538. 26	551. 77	544. 45	608. 97
1 p. m. to 4 p. m	256. 51	276. 84	264. 61	278. 60	296. 34	286. 45	342. 67
4 p. m. to 7 p. m	240. 24	257. 81	250. 24	229. 17	243. 05	235. 06	286. 37
Total, 6 hours	509. 17	518. 30	514. 85	513. 59	529. 29	521. 51	629. 04
Total, 12 hours	1,040. 01	1,051. 47	1,046. 10	1,051. 85	1,073. 42	1,065. 96	1,238. 01
7 p. m. to 10 p.m	101. 87	120. 36	111. 67	116. 94	126. 35	120. 68	339. 03
10 p. m. to 1 a. m	75. 00	92. 91	84. 32	84. 87	100. 36	93. 11	237. 26
Total, 6 hours	194. 78	197. 84	195. 99	201. 81	220. 46	213. 79	576. 29
1 a. m. to 4 a. m	68. 00	76. 37	72. 19	75. 32	85. 12	80. 17	209. 35
4 a. m. to 7 a. m	68. 88	76. 06	71. 92	75. 17	86. 15	79. 16	82. 00
Total, 6 hours	136. 88	152. 43	144. 10	155. 23	161. 47	159. 32	291. 35
Total, 12 hours	331. 66	347. 79	340. 10	357. 04	381. 73	373. 12	867. 64
Total, 24 hours	1,371. 67	1,399. 26	1,386. 20	1,408. 89	1,454. 34	1,439. 08	2,105. 65

[a] One-day experiment.

The data for the rest experiments indicate that the consumption of oxygen varied markedly with the subject, although unfortunately for such deduction the term "rest experiment" does not necessarily signify uniform muscular activity in all experiments thus designated; in fact it does not always signify uniform muscular activity on the different days of each experiment, though the attempt was made to secure such uniformity, inasmuch as the differences in oxygen consumption and other factors studied depend largely on the muscular activity. In experiment No. 58 the variation between the minimum and maximum consumption is relatively large. For example, for the period from 7 a. m. to 1 p. m. the oxygen consumption varied from 121.70 to 157.23 grams on different days. This is probably wholly accounted for by the fact that on the day of minimum consumption the subject during this period remained in bed and was very quiet, while on that of the maximum consumption he was sitting up and writing. That the maximum is more nearly in accord with the conditions for the other experiments is seen by reference to the minimum amounts of oxygen consumed by the remaining subjects. As has been repeatedly pointed out, this subject was unusually quiet, much more so than in any ordinary so-called rest experiment.

As is to be expected, the bodily activity as a whole was much more uniform during the night period and consequently the fluctuations in the oxygen consumption here in large part disappear. The total oxygen consumption of the subject in experiment No. 58 is, however, very small, in fact much smaller than in any experiment thus far made, and indeed smaller than the quantities estimated to have been consumed in any of the earlier experiments. This is perfectly in accord with the observation that the muscular activity of this subject was very much less than in any previous rest experiment. In experiment No. 60, the amounts of oxygen consumed were in all periods, save during the night, larger than in No. 58, but the disagreement between the minimum and maximum is not as great. It is interesting to note that during the night periods, the oxygen consumption was less than with subject H. F. This is in all probability due to the fact that H. F. slept during so much of the day that he was unable to sleep so soundly during the night. Unquestionably the subject of experiment No. 60 secured more profound sleep than did H. F. In fact, the subjective impressions recorded by the two subjects agree wholly with this assumption.

The quantities of oxygen consumed in experiments Nos. 65 and 67 are somewhat greater than in the other two experiments, but these were not typical rest experiments, since on the two days of experiment No. 67 the subject was riding the bicycle ergometer without any external resistance, for eight hours a day; although the amount of external muscular work was probably not very large, the internal muscular work was unquestionably somewhat increased. During the night periods, in which the body activity is much more comparable in all experiments, A. L. L. consumed more oxygen than either of the other two.

The influence of muscular work upon oxygen consumption is strikingly brought out in the results of the work experiments. The consumption of oxygen may rise to 137 grams per hour during a work experiment, as is seen in the period from 10 a. m. to 1 p. m. of experiment No. 57. This increased consumption of oxygen persists as long as the muscular work is continued, and on the day on which severe muscular work was done the high consumption of oxygen continued well into the night. With the cessation of muscular work there was a very rapid fall in the consumption of oxygen, and during the last period of the night, the consumption was nearly that of the corresponding periods during the rest experiment. That it did not reach so low a level as during rest experiments may be explained by the fact that probably during the night there was a consumption of oxygen to convert fat into carbohydrates which had been drawn upon during the period of muscular work.

The large increase in the consumption of oxygen in experiment No. 64, a day of severe work, is wholly in accord with the fact that the muscular work demanded it.

The effect of the diet upon the consumption of oxygen is seen in the comparison of experiments Nos. 62 and 63, the oxygen consumption on the fat diet being slightly greater than on the carbohydrate diet. Experiments Nos. 56 and 57 were also with different diets, but the differences in muscular activity in these two experiments would prevent any direct comparison of the consumption of oxygen.

HOURLY CONSUMPTION OF OXYGEN

The rate of consumption of oxygen per hour and the proportions consumed during the different periods of the day are given in Table 78.

TABLE 78.—*Oxygen consumed by subjects—Average amounts per day and rates and proportions for different periods.*

Subject and kind of experiment.	Duration.	Total amount in 24 hours.	Rates per hour.					Proportions of total for 24 hours.			
			Day periods.		Night periods.		Average for 24 hours.	Day periods.		Night periods.	
			7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.		7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.
Rest experiments.	*Days.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
No. 58, H. F., carbohydrate diet...	3	555.54	24.14	24.58	23.52	20.35	23.15	26.1	26.5	25.4	22.0
No. 60, B. F. D., carbohydrate diet.	3	628.80	31.70	28.68	25.41	19.00	26.20	30.2	27.4	24.3	18.1
Nos. 65-67, A. L. L., carbohydrate diet..............................	4	756.27	37.72	35.20	30.11	23.03	31.51	29.9	27.9	23.9	18.3
Average of rest experiments.	10	657.81	31.84	30.06	26.72	21.02	27.42	29.0	27.4	24.4	19.2
Work experiments.											
No. 56, J. C. W., carbohydrate diet.	3	1,571.87	102.17	99.44	35.27	25.10	65.49	39.0	37.9	13.5	9.6
No. 57, J. C. W., fat diet............	3	1,576.13	105.07	95.16	33.69	28.76	65.67	40.0	36.2	12.8	11.0
No. 61, B. F. D., carbohydrate diet.	1	1,319.09	100.03	65.48	30.23	22.44	54.96	45.8	30.0	13.9	10.3
No. 62, A. L. I., carbohydrate diet.	3	1,386.20	88.54	85.81	32.67	24.02	57.76	38.3	37.2	14.1	10.4
No. 63, A. L. L., fat diet............	3	1,439.08	90.74	86.92	35.63	26.55	59.96	37.8	36.2	14.9	11.1
Average of work experiments......................	13	1,479.92	96.89	89.81	34.00	25.83	61.66	39.3	36.4	13.8	10.5
No. 64, A. L. L., severe work, fat diet..............................	1	2,105.65	101.50	104.84	96.05	48.56	87.74	28.9	29.9	27.4	13.8
Average of work and severe work experiments.........	14	1,524.62	97.22	90.88	38.43	27.45	63.52	38.3	35.8	15.1	10.8

During the rest experiments the average consumption was greatest on the first period of the day, from 7 a. m. to 1 p. m. There was then a gradually decreasing consumption, reaching a minimum in the period from 1 a. m. to 7 a. m. The average rate per hour for twenty-four hours was 27.42 grams, the variation for the four periods being about 4 grams above and below this average. The gradually diminishing quantities used during the periods of the day affect also the percentage distribution through the day, which ranged from 29 per cent during the first period, from 7 a. m. to 1 p. m., to 19.2 per cent in the period from 1 a. m. to 7 a. m. It must still be borne in mind that since even these rest experiments are not strictly comparable in all conditions of muscular activity, these percentage figures represent only an approximation.

In the work experiments the increased demand during the day resulted in a very large hourly consumption, averaging over 90 grams between 7 a. m. and 7 p. m., but the rate of consumption fell almost immediately with the cessation of work, so that from 7 p. m. to 1 a. m. it averaged 34 grams, and during the last period of the night it was a little less than 26 grams per hour. The percentage distribution is likewise affected by the increased demand during the day, so that the average proportion of the total consumption during the first period rose to 39.3 per cent of the total, but during the last period of the night it was as low as 10.5 per cent. With the prolongation of the work into the night, as was the case in experiment No. 64, there was a more even rate per hour and likewise a more even percentage distribution.

The significance of the oxygen consumption is greater when considered in connection with carbon dioxid production, water elimination, and heat production. These relations, together with others, are discussed in detail beyond.

HEAT ELIMINATION.

Energy is expended by the body as heat and as muscular work. In these experiments the muscular work performed is converted into heat, which is measured by the calorimeter along with the heat eliminated by the body in various ways. The total expenditure of energy by the body is therefore expressed in terms of heat. The elimination during three, six, twelve, and twenty-four hour periods is given in detail for the several experiments in Table 117 of the Appendix and summarized in Table 79.

TABLE 79.—*Total heat eliminated during 3-hour periods, metabolism experiments Nos. 56–58 and 60–67.*

Period.	Rest experiments.								
	Experiment No. 58, with H. F., carbohydrate diet.			Experiment No. 60. with B. F. D., carbohydrate diet.			Experiments Nos. 65-67 with A. L. L., carbohydrate diet.		
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
7 a. m. to 10 a. m...	....	....	....	355. 39	376. 58	366. 56	337. 66	456. 20	407. 28
10 a. m. to 1 p. m...	....	....	....	292. 56	317. 04	304. 50	295. 65	421. 08	366. 63
Total, 6 hours....	392. 26	611. 13	522. 36	647. 95	693. 62	671. 05	633. 31	877. 28	773. 91
1 p. m. to 4 p. m...	....	....	....	300. 99	310. 04	304. 40	293. 10	438. 23	355. 70
4 p. m. to 7 p. m...	....	....	....	293. 00	317. 29	302. 83	336. 52	397. 56	364. 11
Total, 6 hours....	423. 96	543. 81	498. 41	593. 99	627. 33	607. 23	629. 62	821. 98	719. 81
Total, 12 hours...	936. 07	1,138. 58	1,020. 77	1,241. 94	1,320. 95	1,278. 28	1,262. 93	1,699. 26	1,493. 72
7 p. m. to 10 p. m...	....	....	....	325. 11	344. 97	336. 09	303. 61	337. 53	318. 17
10 p. m. to 1 a. m...	....	....	....	218. 74	238. 87	229. 02	246. 10	343. 25	284. 18
Total, 6 hours....	434. 47	482. 23	460. 80	563. 71	567. 64	565. 11	555. 29	680. 78	602. 34
1 a. m. to 4 a. m....	....	....	....	184. 72	203. 12	194. 28	235. 00	261. 17	245. 51
4 a. m. to 7 a. m....	....	....	....	180. 55	204. 27	190. 23	215. 27	253. 33	233. 61
Total, 6 hours....	400. 83	442. 98	422. 40	365. 27	407. 39	384. 51	450. 27	509. 56	479. 12
Total, 12 hours...	857. 87	908. 67	883. 20	928. 98	971. 37	949. 62	1,022. 67	1,190. 34	1,081. 46
Total, 24 hours...	1,819. 13	2,047. 25	1,903. 96	2,200. 93	2,269. 46	2,227. 90	2,453. 27	2,721. 93	2,575. 18

TABLE 79.—*Total heat eliminated during 3-hour periods, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Period.	Work experiments.						
	Experiment No. 56, with J. C. W., fat diet.			Experiment No. 57, with J. C. W., carbohydrate diet.			Experiment No. 61, with B. F. D., carbohydrate diet.
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
7 a. m. to 10 a. m.	....	....	....	....	....	....	902.50
10 a. m. to 1 p. m.	....	....	....	....	....	....	1,084.51
Total, 6 hours	1,852.53	2,203.00	2,019.75	1,964.40	2,486.85	2,225.56	1,987.01
1 p. m. to 4 p. m.	....	....	....	....	....	....	790.39
4 p. m. to 7 p. m.	....	....	....	....	....	....	673.16
Total, 6 hours	1,966.14	2,011.51	1,987.77	1,649.29	2,120.07	1,953.06	1,463.55
Total, 12 hours	3,864.04	4,169.14	4,007.52	4,345.50	4,054.23	4,178.62	3,450.56
7 p. m. to 10 p. m.	....	....	....	....	....	....	361.05
10 p. m. to 1 a. m.	....	....	....	....	....	....	253.61
Total, 6 hours	726.28	777.86	747.11	721.04	820.85	768.02	614.66
1 a. m. to 4 a. m.	....	....	....	....	....	....	261.68
4 a. m. to 7 a. m.	....	....	....	....	....	....	238.13
Total, 6 hours	527.09	533.56	529.51	474.71	502.64	488.05	499.81
Total, 12 hours	1,259.84	1,305.73	1,276.62	1,207.85	1,323.49	1,256.07	1,114.47
Total, 24 hours	5,123.88	5,433.41	5,284.13	5,343.99	5,582.38	5,434.70	4,565.03

Period.	Work experiments—Continued.						Severe work experiment No. 64, with A. L. L., fat diet.
	Experiment No. 62, with A. L. L., carbohydrate diet.			Experiment No. 63, with A. L. L., fat diet.			
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
7 a. m. to 10 a. m.	879.78	931 11	900.47	859.94	976.22	925.42	1,047.53
10 a. m. to 1 p. m.	932.62	979.94	955.93	931.25	977.77	951.81	993.36
Total, 6 hours	1,823.14	1,886.34	1,856.40	1,791.19	1,953.99	1,877.23	2,040.89
1 p. m. to 4 p. m.	852.44	944.31	891.50	862.58	960.44	913.45	1,139.04
4 p. m. to 7 p. m.	824.19	927.80	873.69	809.94	842.71	831.78	1,001.53
Total, 6 hours	1,721.51	1,805.56	1,765.19	1,672.52	1,803.15	1,745.22	2,140.57
Total, 12 hours	3,607.85	3,628.70	3,621.59	3,551.19	3,689.67	3,622.45	4,181.46
7 p. m. to 10 p. m.	356.29	389.35	371.18	364.82	407.26	380.39	1,121.56
10 p. m. to 1 a. m.	308.16	331.06	318.82	315.03	341.40	331.17	856.98
Total, 6 hours	685.16	697.51	690.01	706.19	722.29	711.57	1,978.54
1 a. m. to 4 a. m.	257.50	275.85	266.54	275.17	292.23	283.50	682.94
4 a. m. to 7 a. m.	228.75	250.73	243.32	259.61	282.08	272.51	293.76
Total, 6 hours	486.25	526.58	509.86	534.78	568.07	556.01	976.70
Total, 12 hours	1,173.60	1,224.09	1,199.87	1,257.07	1,274.26	1,267.58	2,955.24
Total, 24 hours	4,802.30	4,852.31	4,821.46	4,822.58	4,946.74	4,890.03	7,136.70

For purposes of comparison with the corresponding oxygen, carbon dioxid, and water determinations on previous pages, the minimum, maximum, and average heat eliminations are given. The wide fluctuations between the minimum and maximum observed in the case of the carbon dioxid and oxygen determinations with the subject H. F. in experiment No. 58 are paralleled by similar fluctuations in the heat elimination. The total elimination for the day ranged from 1,819 to 2,047 calories, or an average of 1,903 calories. On comparing this average with the minimum results of experiments Nos. 60 and 65–67, it is seen that the heat production of this subject was much less than of either of the others. This is wholly in accord with the fact that his muscular activity was much less. During the night period the discrepancy between the minimum and maximum is not so great, since the muscular activity was more nearly alike on all three days. In experiment No. 60, while the total heat elimination was greater than in experiment No. 58, the differences between maximum and minimum in large measure disappear, the average heat elimination for twenty-four hours being 2,227 calories, and the extremes less than 50 calories greater or less. In the series of experiments Nos. 65–67 there was a still greater heat elimination, since the muscular activity was greater on these days. The minimum for this series of experiments more nearly corresponds with the average of experiment No. 60. The wide differences between the minimum and maximum here observed will be accounted for by the fact that on the one day of experiment No. 65 the subject was lying in bed asleep for a large portion of the day, while the maximum corresponds to a similar period in experiment No. 67, when he was awake and riding the bicycle ergometer without resistance.

The marked increase in the heat elimination as a result of muscular work is shown in the results for the work experiments. In these experiments the attempt was made to have the muscular work the same on all the days, consequently the discrepancies between the minimum and maximum practically disappear. Indeed, in some of the experiments, notably in Nos. 62 and 63, the agreement is very close. With the severe muscular work in experiment No. 64 the heat elimination rose proportionally. A total of 7,136 calories was eliminated on this day.

HOURLY RATE OF HEAT ELIMINATION.

The hourly rate of elimination of heat, as well as the proportions during the twenty-four hours, are given in Table 80.

Table 80.—*Heat given off by body, including for work experiments the heat equivalent of the external muscular work—Amounts per day, and rates and proportions for different periods.*

Subject and kind of experiment.	Duration.	Total amount in 24 hours.	Rates per hour.					Proportion of total for 24 hours.			
			Day periods.		Night periods.		Average for 24 hours.	Day periods.		Night periods.	
			7 a.m. to 1 p.m.	1 p.m. to 7 p.m.	7 p.m. to 1 a.m.	1 a.m. to 7 a.m.		7 a.m to 1 p.m.	1 p.m. to 7 p.m.	7 p.m. to 1 a.m.	1 a.m. to 7 a.m.
Rest experiments.											
H.F., experiment No. 58, carbohydrate diet	*Days.* 3	*Cals.* 1,904.0	*Cals.* 87.1	*Cals.* 83.1	*Cals.* 76.8	*Cals.* 70.4	*Cals.* 79.3	*P.ct.* 27.4	*P.ct.* 26.2	*P.ct.* 24.2	*P.ct.* 22.2
B.F.D., experiment No., 60 carbohydrate diet	3	2,227.9	111.8	101.2	94.2	64.1	92.8	30.1	27.2	25.4	17.3
A. L. L., experiment No. 65, carbohydrate diet	1	2,453.3	105.6	104.9	113.5	84.9	102.2	25.8	25.7	27.7	20.8
A. L. L., experiment No. 66, carbohydrate diet	1	2,470.5	125.1	111.2	92.5	82.9	102.9	30.4	27.0	22.5	20.1
A. L. L., experiment No. 67, carbohydrate diet	2	2,688.5	142.7	131.8	97.8	75.8	112.0	31.8	29.4	21.9	16.9
Average for above rest experiments	10	2,269.7	111.3	103.3	91.5	72.3	94.6	29.4	27.3	24.2	19.1
Work experiments.											
J. C. W., experiment No. 56, fat diet:											
Heat equivalent of external muscular work	3	569.3	48.0	46.9				50.6	49.4		
Total heat eliminated		5,284.1	336.6	331.3	124.5	88.3	220.2	38.2	37.6	14.2	10.0
J. C. W., experiment No. 57, carbohydrate diet:											
Heat equivalent of external muscular work	3	602.3	54.6	45.8				54.4	45.6		
Total heat eliminated		5,434.7	370.9	325.5	128.0	81.3	226.4	41.0	35.9	14.1	9.0
B. F. D., experiment No. 61, carbohydrate diet:											
Heat equivalent of external muscular work	1	419.0	46.3	23.5				66.3	33.7		
Total heat eliminated		4,565.0	331.2	243.9	102.4	83.3	190.2	43.5	32.1	13.5	10.9
A. L. L., experiment No. 62, carbohydrate diet:											
Heat equivalent of external muscular work	3	459.0	38.9	37.6				50.8	49.2		
Total heat eliminated		4,821.5	309.4	294.2	115.0	85.0	200.9	38.5	36.6	14.3	10.6
A. L. L., experiment No. 63, fat diet:											
Heat equivalent of external muscular work	3	459.3	40.7	35.9				53.1	46.9		
Total heat eliminated		4,890.0	312.9	290.9	118.6	92.7	203.8	38.4	35.7	14.6	11.3
A. L. L., experiment No. 64, fat diet:											
Heat equivalent of external muscular work	1	957.0	50.5	51.0	44.2	13.8	39.9	31.6	32.0	27.7	8.7
Total heat eliminated		7,136.7	340.1	356.8	329.8	162.8	297.4	28.6	30.0	27.7	13.7
Average for above work experiments:											
Heat equivalent of external muscular work	14	546.1	46.0	40.9							
Heat eliminated		5,213.8	333.0	309.0	135.0	92.0	217.2	38.3	35.6	15.5	10.6

The data here given show that in all the rest experiments the heat elimination was greatest during those periods in which the subject was awake and least during the sleeping periods. A comparison between the subject H. F. and the others shows strikingly the diminished heat elimination of this subject during the two day periods. As for the night periods, from 1 a. m. to 7 a. m. the average per hour was somewhat greater than in experiment No. 60, but the average for the twenty-four hours was over 13 calories less than for any other rest experiment. The increased heat production in experiment No. 67 is accounted for by the fact that the subject was engaged in light exercise and not in complete rest. The proportion of the total heat elimination during the different periods of the day corresponds with the rate per hour. In the average for the rest experiments, 29.4 per cent of the heat was eliminated during the period from 7 a. m. to 1 p. m., with a gradually diminishing rate through the day; the minimum, 19.1 per cent, was during the period from 1 a. m. to 7 a. m.

HEAT EQUIVALENT OF EXTERNAL MUSCULAR WORK.

Detailed data regarding the heat equivalent of the external muscular work done by the subjects on the bicycle ergometer are given in Table 120 of the Appendix. The average results per day are included with the data for the work experiments in Table 80. In experiment No. 56, for example, the total heat eliminated per day amounted to 5,284.1 calories, of which 569.3 calories was the equivalent of the external muscular work done. Since the work was all done in the day periods, i. e., from 7 a. m. to 7 p. m., the large proportion of the increased heat elimination appears during these periods. This is likewise true for all the work experiments, save that of experiment No. 64, where the working period was extended to cover parts of each of the four 6-hour periods. The heat elimination during the period from 1 a. m. to 7 a.m. in all the work experiments was but slightly greater than that during the corresponding rest experiments. The percentage distribution of the heat is much more uneven, owing to the increased elimination during the day periods, and from 1 a. m. to 7 a. m. as low as 9 per cent of the total heat was eliminated. The heat of external muscular work shows that in general a little more than half of the work was performed during the morning period, from 7 a. m. to 1 p. m.; but in experiment No. 61 two-thirds of the day's allotment was done during the morning periods. In experiment No. 64, with the severe muscular work, the distribution of the work was fairly even throughout all the periods except the last one, i. e., from 1 a. m. to 7 a. m. As has been frequently observed in experiments of this nature, the subjects did not seem to sleep as well after a day of work as after a day of rest. This doubtless explains the larger heat production during the period from 1 a. m. to 7 a. m. after work as compared with the same period during rest.

ENERGY ELIMINATED IN DIFFERENT WAYS.

Energy produced by the body leaves it in four ways—as heat eliminated by radiation and conduction, as sensible heat of excreta, as heat latent in the water vaporized from lungs and skin, and as external muscular work. The sensible heat of urine and feces is the product of the difference between body temperature (37°) and the temperature of the calorimeter (20°), the specific heat of these materials (urine 1.0, feces 0.9) and their amount. The heat in the water vaporized from the lungs and skin is found from the amount of water thus vaporized and the latent heat of water vapor, namely, 0.592 calorie per gram. The heat equivalent of external muscular work is computed from the number of revolutions of the bicycle ergometer and its calibration factor.. The sum of the three quantities of heat thus ascertained subtracted from the total amount eliminated gives the quantity given off by radiation and conduction. The different quantities of energy thus eliminated and the proportion of the total that each comprises are given for all the experiments in Table 81.

TABLE 81.—*Energy given off by the body in different ways—Amounts per day and proportions of total eliminated in different ways.*

Subject and kind of experiment.	Days covered by experiments.	Quantities of energy per day.					Energy expressed in proportions of total.			
		Heat eliminated.					Heat eliminated.			
		By radiation and conduction.	In urine and feces.	In water vaporized from lungs and skin.	Heat equivalent of external muscular work.	Total.	By radiation and conduction.	In urine and feces.	In water vaporized from lungs and skin.	Heat equivalent of external muscular work.
Rest experiments.										
Experiment No. 58, with H. F., carbohydrate diet	3	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maximum	......	1,555	8	491	......	2,047	......	......	......	......
Minimum	......	1,347	8	300	......	1,819	......	......	......	......
Average	......	1,471	8	425	......	1,904	77.3	0.4	22.3	......
Experiment No. 60, with B. F. D., carbohydrate diet	3	......	......	......		......	......	......	......	......
Maximum	......	1,593	25	651	......	2,269	......	......	......	......
Minimum	......	2,021	19	161	......	2,201	......	......	......	......
Average	......	1,746	22	460	......	2,228	78.4	1.0	20.6	......
Experiment No. 65, with A. L. L., carbohydrate diet	1	1,704	20	729	......	2,453	69.5	.8	29.7	......
Experiment No. 66, with A. L. L., carbohydrate diet	1	1,824	19	628	......	2,471	73.8	.8	25.4	......
Experiment No. 67, with A. L. L., carbohydrate diet	2	......	......	......	......	......	......	......	......	......
Maximum	......	2,158	24	567	......	2,722	......	......	......	......
Minimum	......	2,068	20	540	......	2,655	......	......	......	......
Average	......	2,113	22	554	......	2,689	78.6	.8	20.6	......
Rest experiments	10	......	......	......	......	......	......	......	......	......
Maximum	......	2,158	25	729	......	2,722	......	......	......	......
Minimum	......	1,347	8	161	......	1,819	......	......	......	......
Average	......	1,741	17	512	......	2,270	76.7	.8	22.5	......
Work experiments.										
Experiment No. 56, with J. C. W., fat diet	3	......	......	......	......	......	......	......	......	......
Maximum	......	4,011	29	801	601	5,433	......	......	......	......
Minimum	......	3,829	20	737	538	5,124	......	......	......	......
Average	......	3,933	23	759	569	5,284	74.4	.4	14.4	10.8
Experiment No. 57, with J. C. W., carbohydrate diet	3	......	......	......	......	......	......	......	......	......
Maximum	......	4,151	22	900	657	5,582	......	......	......	......
Minimum	......	3,857	20	752	563	5,344	......	......	......	......
Average	......	3,968	21	844	602	5,435	73.0	.4	15.5	11.1
Experiment No. 61, with B. F. D., carbohydrate diet	1	3,317	17	812	419	4,565	72.7	.4	17.8	9.2

TABLE 81.—*Energy given off by the body in different ways—Amounts per day and proportions of total eliminated in different ways*—Continued.

Subject and kind of experiment.	Days covered by experiments.	Quantities of energy per day.					Energy expressed in proportions of total.			
		Heat eliminated.					Heat eliminated.			
		By radiation and conduction.	In urine and feces.	In water vaporized from lungs and skin.	Heat equivalent of external muscular work.	Total.	By radiation and conduction.	In urine and feces.	In water vaporized from lungs and skin.	Heat equivalent of external muscular work.
Work experiments—Continued.										
		Cals.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Experiment No. 62, with A. L. L., carbohydrate diet	3									
Maximum		3,676	15	766	460	4,852				
Minimum		3,565	12	701	458	4,802				
Average		3,606	13	744	459	4,821	74.8	.3	15.4	9.5
Experiment No. 63, with A. L. L., fat diet	3									
Maximum		3,683	33	786	460	4,947				
Minimum		3,557	18	775	458	4,823				
Average		3,623	28	780	459	4,890	74.1	.6	16.0	9.4
Experiment No. 64, with A. L. L., fat diet	1	5,278	21	881	957	7,137	74.0	.3	12.3	13.4
Work experiments	14									
Maximum		4,151	33	900	957	7,137				
Minimum		3,317	12	701	419	4,565				
Average		3,856	21	791	546	5,214	74.0	.4	15.2	10.4

During the rest experiments the heat eliminated by radiation and conduction varied somewhat with the subject. It should here also be borne in mind that experiment No. 67 would more properly be designated light exercise rather than rest. The sensible heat escaping in the urine and feces was practically the same in all the rest experiments save that with H. F., in which, because of the small amount voided, it was only about one-third of the others. In the water vaporized from the lungs and skin the variations ranged from 161 calories in experiment No. 60 to 729 calories in experiment No. 65. As has been previously stated, experiment No. 60 can hardly be used for comparison, owing to the abnormal ventilation conditions. With regard to the percentage distribution, approximately 76.7 per cent of the energy was eliminated by radiation and conduction, less than 1 per cent in the sensible heat of urine and feces, and 22.5 per cent in the water vaporized from the lungs and skin.

In the work experiments the greatest increase in the heat elimination is in that of radiation and conduction. The sensible heat of urine and feces remained practically that of the rest experiments. There was an increase in the amount of heat absorbed by the vaporization of water from the lungs and skin, but not at all in proportion to the total increase in heat. The heat equivalent of external muscular work varied from 419 to 957 calories, the largest amount, of course, being on the day with severe muscular work. In regard to the percentage distribution, here, again, about 75 per cent was eliminated by radiation and conduction and less than 1 per cent in the sensible heat of urine and feces; about 15 per cent was given off in the water vaporized from the lungs and skin and 10.4 per cent in the heat equivalent of external muscular work.

COMPARISON OF PERCENTAGES OF CARBON DIOXID, WATER, AND HEAT ELIMINATED, AND OXYGEN ABSORBED DURING DIFFERENT PERIODS OF THE DAY.

It is of importance to note not only how much carbon dioxid, water, and heat result from metabolism during a given day and how much oxygen is absorbed, but also the relationships between these factors. This can be studied in a number of ways, one of which is based upon the comparison of the proportions of the total daily amounts of each of the factors which are measured during the different periods of the day. These data are summarized from the preceding tables for comparison in Table 82.

TABLE 82.—*Proportions, by periods, of the total daily amounts of carbon dioxid, water, and heat eliminated, and oxygen absorbed.*

Period.	Rest experiments.											
	Experiment No. 58, with H. F., carbohydrate diet.				Experiment No. 60, with B. F. D., carbohydrate diet.				Experiments Nos. 65–67, with A. L. L., carbohydrate diet.			
	Carbon dioxid.	Water.	Oxygen.	Heat.	Carbon dioxid.	Water.	Oxygen.	Heat.	Carbon dioxid.	Water.	Oxygen.	Heat.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
7 a. m. to 10 a. m	......	......	......	......	15.82	14.13	17.07	16.45	15.43	13.44	16.22	15.81
10 a. m. to 1 p. m	......	......	......	......	13.52	12.21	13.18	13.67	13.50	12.78	13.70	14.24
Total, 6 hours	24.13	24.00	26.07	27.43	29.34	26.34	30.25	30.12	28.93	26.22	29.92	30.05
1 p. m. to 4 p. m	......	......	......	......	14.07	13.43	14.29	13.66	14.81	12.51	14.72	13.81
4 p. m. to 7 p. m	......	......	......	......	13.75	13.81	13.08	13.60	13.67	12.22	13.20	14.13
Total, 6 hours	28.95	23.90	26.55	26.18	27.82	27.24	27.37	27.26	28.48	24.73	27.92	27.94
Total, 12 hours	53.08	47.90	52.62	53.61	57.16	53.58	57.62	57.39	57.41	50.96	57.84	57.99
7 p. m. to 10 p. m	......	......	......	......	15.61	13.02	15.43	15.08	12.84	12.35	12.67	12.35
10 p. m. to 1 a. m	......	......	......	......	10.17	12.18	8.82	10.29	12.39	12.99	11.22	11.04
Total, 6 hours	25.67	26.50	25.40	24.20	25.78	25.20	24.25	25.37	25.23	25.34	23.89	23.39
1 a. m. to 4 a. m	......	......	......	......	8.25	10.60	8.63	8.71	8.74	12.45	9.69	9.54
4 a. m. to 7 a. m	......	......	......	......	8.81	10.62	9.50	8.55	8.62	11.25	8.58	9.08
Total, 6 hours	21.25	25.60	21.98	22.19	17.06	21.22	18.13	17.26	17.36	23.70	18.27	18.62
Total, 12 hours	46.92	52.10	47.38	46.39	42.84	46.42	42.38	42.61	42.59	49.04	42.16	42.01
Total, 24 hours	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 82.—*Proportions, by periods, of the total daily amounts of carbon dioxid, water, and heat eliminated, and oxygen absorbed*—Continued.

Period.	Work experiments.											
	Experiment No. 56, with J. C. W., fat diet.				Experiment No. 57, with J. C. W., carbohydrate diet.				Experiment No. 61, with B. F. D., carbohydrate diet.			
	Carbon dioxid.	Water.	Oxygen.	Heat.	Carbon dioxid.	Water.	Oxygen.	Heat.	Carbon dioxid.	Water.	Oxygen.	Heat.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
7 a. m. to 10 a. m.	......	......	......	......	18.84	21.18	17.62	......	22.73	18.96	20.35	19.77
10 a. m. to 1 p. m.	......	......	......	......	22.34	23.09	22.38	......	24.79	19.41	25.50	23.76
Total, 6 hours	39.08	39.02	39.00	38.22	41.18	44.27	40.00	40.95	47.52	38.37	45.85	43.53
1 p. m. to 4 p. m.	......	......	......	......	18.27	18.36	18.93	......	16.72	19.70	16.81	17.31
4 p. m. to 7 p. m.	......	......	......	......	17.61	19.05	17.30	......	13.20	19.29	13.21	14.75
Total, 6 hours	38.20	41.72	37.95	37.62	35.88	37.41	36.23	35.94	29.92	38.99	30.02	32.06
Total, 12 hours	77.28	80.74	76.95	75.84	77.06	81.68	76.23	76.89	77.44	77.36	75.87	75.59
7 p. m. to 10 p. m.	......	......	......	......	8.26	4.89	7.28	......	7.37	6.20	8.17	7.92
10 p. m. to 1 a. m.	......	......	......	......	5.97	4.66	5.54	......	5.61	5.73	5.68	5.55
Total, 6 hours	13.43	9.88	13.47	14.14	14.23	9.55	12.82	14.13	12.98	11.93	13.85	13.47
1 a. m. to 4 a. m.	......	......	......	......	4.29	4.40	6.69	......	5.16	5.56	5.52	5.73
4 a. m. to 7 a. m.	......	......	......	......	4.44	4.37	4.26	......	4.42	5.15	4.76	5.21
Total, 6 hours	9.29	9.38	9.58	10.02	8.73	8.77	10.95	8.98	9.58	10.71	10.28	10.94
Total, 12 hours	22.72	19.26	23.05	24.16	22.94	18.32	23.77	23.11	22.56	22.64	24.13	24.41
Total, 24 hours	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Period.	Work experiments—Continued.											
	Experiment No. 62, with A. L. L., carbohydrate diet.				Experiment No. 63, with A. L. L., fat diet.				Experiment No. 64, with A. L. L., fat diet. Severe work.			
	Carbon dioxid.	Water.	Oxygen.	Heat.	Carbon dioxid.	Water.	Oxygen.	Heat.	Carbon dioxid.	Water.	Oxygen.	Heat.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
7 a. m. to 10 a. m.	19.73	20.60	19.85	18.67	20.12	20.81	19.82	18.92	15.72	13.98	16.07	14.68
10 a. m. to 1 p. m.	18.97	20.53	18.47	19.83	18.73	20.69	18.01	19.47	13.00	13.74	12.86	13.91
Total, 6 hours	38.70	41.13	38.32	38.50	38.85	41.50	37.83	38.39	28.72	27.72	28.93	28.59
1 p. m. to 4 p. m.	19.09	20.37	19.09	18.49	19.85	20.87	19.92	18.67	16.73	13.95	16.27	15.97
4 p. m. to 7 p. m.	18.17	20.66	18.05	18.12	16.43	20.83	16.32	17.02	14.35	13.75	13.60	14.03
Total, 6 hours	37.26	41.03	37.14	36.61	36.28	41.70	36.24	35.69	31.08	27.70	29.87	30.00
Total, 12 hours	75.96	82.16	75.46	75.11	75.13	83.20	74.07	74.08	59.80	55.42	58.80	58.59
7 p. m. to 10 p. m.	7.88	4.29	8.06	7.70	7.79	4.23	8.39	7.78	16.39	14.12	16.10	15.71
10 p. m. to 1 a. m.	6.15	4.79	6.08	6.61	6.74	4.42	6.47	6.77	10.65	13.91	11.27	12.01
Total, 6 hours	14.03	9.08	14.14	14.31	14.53	8.65	14.86	14.55	27.04	28.03	27.37	27.72
1 a. m. to 4 a. m.	5.12	4.39	5.21	5.53	5.05	3.97	5.57	5.80	9.53	13.75	9.94	9.57
4 a. m. to 7 a. m.	4.89	4.37	5.19	5.05	5.29	4.18	5.50	5.57	3.63	2.80	3.90	4.12
Total, 6 hours	10.01	8.76	10.40	10.58	10.34	8.15	11.07	11.37	13.16	16.55	13.84	13.69
Total, 12 hours	24.04	17.84	24.54	24.89	24.87	16.80	25.93	25.92	40.20	44.58	41.20	41.41
Total, 24 hours	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

In general, the proportions of carbon dioxid, oxygen, and heat during the different periods agree fairly well with each other, while that of water frequently differs considerably from any of them. In comparing the carbon dioxid output and oxygen intake with the heat output, it is seen that on the whole the closer agreement lies between the oxygen and heat, and indeed in general the proportions of oxygen absorbed during a given period are very close to those of the heat eliminated. In the rest experiments about 29.5 per cent of the total oxygen intake and carbon dioxid and heat output is found during the first period—from 7 a. m. to 1 p. m. During the next 6-hour period the proportion is somewhat lower, averaging about 27.6 per cent, while during the night periods the percentage falls, for the first one to 24.8 per cent and for the last one to 18.1. Of the total energy and carbon dioxid output and oxygen intake, about 56 per cent corresponds to the day period—from 7 a. m. to 7 p. m.—and 44 per cent to the night period. In work experiments the proportions are, as was shown in the previous discussions, considerably altered, depending in large measure upon the hour in which the work was done. In all the work experiments here reported, except No. 64, about 75 per cent of the total carbon dioxid and heat output and oxygen intake corresponds to the day period—from 7 a. m. to 7 p. m.—which includes the working hours, the remaining 25 per cent being given off during the night period. When the work was extended over a good share of the night as well as the day, the proportions were altered so that only about 59 per cent of the transformations took place during the day and 41 per cent during the night period.

POSSIBILITY OF STORAGE OF OXYGEN.

Throughout this bulletin the discussion of the consumption of oxygen has had reference to the quantity which the subject actually obtained from the ventilating air current, without regard to what use was made of it in the body. It is believed that there may be, under certain conditions, a noticeable storage of oxygen in the tissues, and some oxygen is utilized, of course, when fat is converted into carbohydrates. But the results of the experiments here reported show that, in general, when differences in the character of the diet are taken into consideration, the consumption of oxygen is very closely parallel to the elimination of carbon dioxid, and there is no evidence of a marked storage or retention of oxygen in the tissues or of any extensive formation of glycogen from fat. It would therefore seem probable that the fluctuations in oxygen consumption are proportional to the carbon dioxid elimination and subject to the same variations.

ELIMINATION OF CARBON DIOXID AND WATER AND INTAKE OF OXYGEN PER KILOGRAM OF BODY WEIGHT.

Since it is commonly believed that the total metabolism is in large measure dependent upon the body weight of the subject, it is interesting to compute the quantities of carbon dioxid and water eliminated and of oxygen absorbed per kilogram of body weight. To make the comparison still more complete, the rates for the different periods of the day and for the twenty-four hours should likewise be computed. These data for the experiments here reported are given in Table 83.

TABLE 83.—*Hourly rates of elimination of carbon dioxid and water and intake of oxygen per kilogram of body weight—Rates in different periods and for twenty-four hours.*

Kind and subject of experiment.	Average body weight.	Duration.	Amounts eliminated per hour per kilogram of body weight.				
			Day periods.		Night periods.		Average for 24 hours.
			7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.	
CARBON-DIOXID.							
Rest experiments.	*Kgms.*	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 58, with H. F., carbohydrate diet	71.6	3	0.37	0.44	0.39	0.33	0.38
No. 60, with B. F. D., carbohydrate diet	66.8	3	.57	.54	.50	.33	.49
Nos. 65-67, with A. L. L., carbohydrate diet	72.7	4	.59	.58	.51	.35	.51
Average, Nos. 58, 60, 65-67	....	10	.52	.53	.47	.34	.47
Work experiments.							
No. 56, with J. C. W., fat diet	75.9	3	1.51	1.48	.52	.36	.97
No. 57, with J. C. W., carbohydrate diet	76.6	3	1.80	1.57	.62	.38	1.09
No. 61, with B. F. D., carbohydrate diet	67.0	1	1.89	1.19	.52	.38	.99
No. 62, with A. L. L., carbohydrate diet	75.4	3	1.46	1.41	.53	.38	.94
No. 63, with A. L. L., fat diet	73.4	3	1.40	1.31	.52	.37	.90
Average, Nos. 56, 57, 61, 62, 63	....	13	1.57	1.42	.55	.37	.98
No. 64, with A. L. L., fat diet, severe work	72.2	1	1.55	1.68	1.46	.71	1.35
Average, Nos. 56, 57, 61, 62, 63, 64	....	14	1.57	1.44	.61	.39	1.01
Average, all experiments	....	24	1.13	1.06	.55	.37	.79
WATER.							
Rest experiments.							
No. 58, with H. F., carbohydrate diet	71.6	3	.40	.40	.44	.43	.42
No. 60, with B. F. D., carbohydrate diet	66.8	3	.53	.55	.51	.43	.51
Nos. 65-67, with A. L. L., carbohydrate diet	72.7	4	.55	.52	.53	.50	.53
Average, Nos. 58, 60, 65-67	....	10	.50	.49	.50	.46	.49
Work experiments.							
No. 56, with J. C. W., fat diet	75.9	3	3.37	3.60	.85	.81	2.16
No. 57, with J. C. W., carbohydrate diet	76.6	3	3.89	3.29	.84	.77	2.20
No. 61, with B. F. D., carbohydrate diet	67.0	1	2.74	2.78	.85	.76	1.78
No. 62, with A. L. L., carbohydrate diet	75.4	3	3.01	3.00	.66	.64	1.83
No. 63, with A. L. L., fat diet	73.4	3	3.48	3.50	.73	.68	2.10
Average, Nos. 56, 57, 61, 62, 63	....	13	3.38	3.30	.78	.73	2.05
No. 64, with A. L. L., fat diet, severe work	72.2	1	3.80	3.80	3.84	2.27	3.43
Average, Nos. 56, 57, 61, 62, 63, 64	....	14	3.41	3.34	1.00	.84	2.15
Average, all experiments	....	24	2.20	2.15	.79	.68	1.46

TABLE 83.—*Hourly rates of elimination of carbon dioxid and water and intake of oxygen per kilogram of body weight—Rates in different periods and for twenty-four hours*—Continued.

Kind and subject of experiment.	Average body weight.	Duration.	Amounts absorbed per hour per kilogram of body weight.				
			Day periods.		Night periods.		Average for 24 hours.
			7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.	
OXYGEN.							
Rest experiments.	*Kgms.*	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 58, with H. F., carbohydrate diet	71.6	3	.34	.34	.33	.28	.32
No. 60, with B. F. D., carbohydrate diet	66.8	3	.47	.43	.38	.28	.39
Nos. 65-67, with A. L. L., carbohydrate diet	72.7	4	.52	.48	.41	.32	.43
Average, Nos. 58, 60, 65-67		10	.45	.42	.38	.30	.39
Work experiments.							
No. 56, with J. C. W., fat diet	75.9	3	1.35	1.31	.46	.33	.86
No. 57, with J. C. W., carbohydrate diet	76.6	3	1.37	1.24	.44	.38	.86
No. 61, with B. F. D., carbohydrate diet	67.0	1	1.49	.98	.45	.33	.82
No. 62, with A. L. L., carbohydrate diet	75.4	3	1.17	1.14	.43	.32	.77
No. 63, with A. L. L., fat diet	73.4	3	1.24	1.18	.49	.36	.82
Average, Nos. 56, 57, 61, 62, 63		13	1.30	1.20	.45	.35	.83
No. 64, with A. L. L., fat diet, severe work	72.2	1	1.41	1.45	1.33	.67	1.22
Average, Nos. 56, 57, 61, 62, 63, 64		14	1.31	1.22	.51	.37	.86
Average, all experiments		24	.95	.89	.46	.34	.66

The computations are made for both the rest and the work experiments. During the rest experiments the amounts of carbon dioxid eliminated per hour per kilogram of body weight ranged on the average from 0.52 gram during the day periods to 0.34 gram during the last of the night periods. The average for the twenty-four hours is 0.47 gram. The conditions affecting the elimination of carbon dioxid have been fully discussed before; it is only necessary to recall the fact that the degree of muscular activity determines in large measure the carbon dioxid output. In experiment No. 58, in which the muscular activity was at the lowest, we would expect to find the values lower than the average, and the figures show that this is the case. In the work experiments the amount of carbon dioxid eliminated rose during the day to an average of 1.57 grams for the morning period in which the larger share of the work was done; and during the last period of the night it fell again to nearly that of the same period in rest experiments, namely, 0.37 gram. The average for the whole day is 0.98 gram. The influence of excessive muscular exercise, as in experiment No. 64, on all of these average amounts is seen when the results for corresponding periods in the different experiments are compared. In this case the averages per hour remained more nearly constant for the whole day, and the figure for the last period of the night was nearly twice that found in the same period in rest and other work experiments. During this night period the subject did some work with the bicycle ergometer, but in all the other experiments the subjects were sleeping at this time. The average for the day is, furthermore, considerably higher than that in the other work experiments.

The water elimination is likewise subject to certain fluctuations, depending upon the muscular activity of the subject and the nature of the experiment. During the rest experiments the fluctuations were not very marked, the elimination being fairly evenly distributed throughout the whole twenty-four hours. The average amount per hour was not far from 0.5 gram. In the work experiments, on the contrary, the larger proportion of the water was eliminated during the periods of increased muscular activity.

The consumption of oxygen is affected not only by the degree of muscular activity of the subject, but also by the nature of the diet, as has been pointed out in previous discussion. During the rest experiments the intake ranged from 0.28 to 0.52 gram, and averaged about 0.4 gram per hour per kilogram of body weight. The distribution during the twenty-four hours is quite comparable with that of carbon dioxid, the largest rate per hour being observed during the day periods and the lowest during the last night period.

As the elimination of carbon dioxid per kilogram of body weight and per hour increased very greatly during work, so likewise the absorption of oxygen per hour and per kilogram was very much greater during the day periods than during the corresponding periods of the rest experiments. The absorption fell off, however, till in the last period of the night it was not much greater than during the corresponding period of the rest experiments.

The effect of greater muscular work on the hourly rate is noticed in experiment No. 64, and the effect of the muscular work during the night period is especially observed during the period from 1 a. m. to 7 a. m., with a rate of 0.67 gram of oxygen per kilogram of body weight per hour against 0.35 gram, the average of the ordinary work experiments, and 0.30 gram, the average of the rest experiments.

ELIMINATION OF HEAT PER KILOGRAM OF BODY WEIGHT AND PER SQUARE METER OF BODY SURFACE.

The heat elimination is also commonly considered as being proportional to the body weight, and during rest nearly proportional to the surface area of the body. For purposes of comparison the heat per hour per kilogram of body weight and per square meter of body surface for the experiments here reported are recorded in Table 84. For further comparison the hourly rates of elimination in different parts of the day and averages for the whole day are likewise given in the table.

Table 84.—*Hourly rates of elimination of heat per kilogram of body weight and per square meter of body surface of different subjects—Rates in different parts of day and averages for whole day.*

Subject and kind of experiment.	Body weight.	Duration.	Heat eliminated per hour per kilogram of body weight.				
			7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.	Average for 24 hours.
Rest experiments.	*Kgms.*	*Days.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*
H. F., experiment No. 58, carbohydrate diet	71.6	3	1.22	1.16	1.07	0.98	1.11
B. F. D., experiment No. 60, carbohydrate diet	66.7	3	1.68	1.52	1.41	.96	1.39
A. L. L., experiment No. 65, carbohydrate diet	72.5	1	1.46	1.45	1.57	1.17	1.41
A. L. L., experiment No. 66, carbohydrate diet	73.0	1	1.71	1.52	1.27	1.14	1.41
A. L. L., experiment No. 67, carbohydrate diet	72.7	2	1.96	1.81	1.35	1.04	1.54
Average of experiments Nos. 65–67	72.7	4	1.77	1.65	1.38	1.10	1.48
Average for above rest experiments	....	10	1.58	1.46	1.30	1.02	1.34
Work experiments.							
J. C. W., experiment No. 56, fat diet:							
Heat equivalent of external muscular work	....	3	.63	.62	....	....	....
Total heat eliminated	75.9	3	4.43	4.36	1.64	1.16	2.90
J. C. W., experiment No. 57, carbohydrate diet:							
Heat equivalent of external muscular work	....	3	.71	.60	....	....	....
Total heat eliminated	76.6	3	4.84	4.25	1.67	1.06	2.96
B. F. D., experiment No. 61, carbohydrate diet:							
Heat equivalent of external muscular work	....	1	.69	.35	....	....	....
Total heat eliminated	67.0	1	4.94	3.64	1.53	1.24	2.84
A. L. L., experiment No. 62, carbohydrate diet:							
Heat equivalent of external muscular work	....	3	.52	.50	....	....	....
Total heat eliminated	75.4	3	4.10	3.90	1.53	1.13	2.66
A. L. L., experiment No. 63, fat diet:							
Heat equivalent of external muscular work	....	3	.55	.49	....	....	....
Total heat eliminated	73.4	3	4.26	3.96	1.62	1.26	2.78
Average for above work experiments:							
Heat equivalent of external muscular work	....	13	.61	.54	....	....	....
Total heat eliminated	....	13	4.45	4.08	1.61	1.16	2.83
Severe work experiment.							
A. L. L., experiment No. 64, fat diet:							
Heat equivalent of external muscular work	....	1	.70	.71	.61	.19	.55
Total heat eliminated	72.2	1	4.71	4.94	4.57	2.25	4.12
Average for all above work experiments:							
Heat equivalent of external muscular work	....	14	.62	.55	....	....	....
Total heat eliminated	....	14	4.47	4.14	1.82	1.24	2.92

TABLE 84.—*Hourly rates of elimination of heat per kilogram of body weight and per square meter of body surface of different subjects—Rates in different parts of day and averages for whole day*—Continued.

Subject and kind of experiment.	Duration.	Heat eliminated per hour per square meter of body surface.				
		7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.	Average for 24 hours.
Rest experiments.	*Days.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*
H. F., experiment No. 58, carbohydrate diet	3	41.1	39.2	36.2	33.2	37.4
B. F. D., experiment No. 60, carbohydrate diet	3	55.1	49.9	46.4	31.6	45.7
A. L. L., experiment No. 65, carbohydrate diet	1	49.3	49.0	53.0	39.7	47.8
A. L. L., experiment No. 66, carbohydrate diet	1	58.5	52.0	43.2	38.7	48.1
A. L. L., experiment No. 67, carbohydrate diet	2	66.7	61.6	45.7	35.4	52.3
Average of experiments Nos. 65–67	4	60.3	56.0	46.9	37.3	50.1
Average for above rest experiments	10	53.0	49.2	43.5	34.4	45.0
Work experiments.						
J. C. W., experiment No. 56, fat diet:						
Heat equivalent of external muscular work	3	21.6	21.1	....	....	....
Total heat eliminated	3	151.6	149.2	56.1	39.8	99.2
J. C. W., experiment No. 57, carbohydrate diet:						
Heat equivalent of external muscular work	3	24.6	20.6	....	....	....
Total heat eliminated	3	167.1	146.6	57.7	36.6	102.0
B. F. D., experiment No. 61, carbohydrate diet:						
Heat equivalent of external muscular work	1	22.8	11.6	....	....	....
Total heat eliminated	1	163.2	120.1	50.4	41.0	93.7
A. L. L., experiment No. 62, carbohydrate diet:						
Heat equivalent of external muscular work	3	18.2	17.6	....	....	....
Total heat eliminated	3	144.6	137.5	53.7	39.7	93.9
A. L. L., experiment No. 63, fat diet:						
Heat equivalent of external muscular work	3	19.0	16.8	....	....	....
Total heat eliminated	3	146.2	135.9	55.4	43.3	95.2
Average for above work experiments:						
Heat equivalent of external muscular work	13	21.0	18.5	....	....	....
Total heat eliminated	13	153.2	140.6	55.3	39.9	97.3
Severe work experiment.						
A. L. L., experiment No. 64, fat diet:						
Heat equivalent of external muscular work	1	23.6	23.8	20.7	6.4	18.6
Total heat eliminated	1	158.9	166.7	154.1	76.1	139.0
Average for all above experiments:						
Heat equivalent of external muscular work	14	21.2	18.8	....	....	....
Total heat eliminated	14	153.6	142.5	62.4	42.5	100.3

In the rest experiments the heat elimination per kilogram of body weight was lowest in experiment No. 58 and highest in experiment No. 67, which, as has been pointed out, would more properly be designated as a light exercise rather than a rest experiment. Similarly, the average heat elimination per square meter of body surface was lowest in experiment No. 58 and highest in experiment No. 67. Experiments Nos. 60, 65, and 66, on the other hand, show an average heat elimination per kilogram of body weight and per square meter of body surface much the same for all three experiments. The averages are probably somewhat greater than would normally be the case in experiments which are distinctly rest experiments. In the averages for all the experiments here designated as rest experiments, from 7 a. m. to 1 p. m. there were 1.58 calories for every kilogram of body weight and 53.0 calories per square meter of body surface. During the next period the corresponding values are 1.46 calories and 49.2 calories. They diminished during the first night period, from 7 p. m. to 1 a. m., to 1.30 calories and 43.5 calories, respectively, and during the last period of the night fell still further, to 1.02 calories and 34.4 calories.

The heat equivalent of the external muscular work in the work experiments is included in the table. This varies with the quantity of work done, as does also the total heat elimination, and the hourly rate, both per kilogram of body weight and per square meter of body surface, is directly affected by the periods of work. This is especially noted in the severe work experiment, where the work extended over the greater portion of the twenty-four hours. It is interesting to note that on the average for the work experiments, other than No. 64, the heat elimination per kilogram of body weight and per square meter of body surface was not much greater during the period from 1 a. m. to 7 a. m. than during the corresponding period of the rest experiments. Indeed, in the case of experiment No. 57, the results for this last night period were quite close to those for the rest experiments for the same period. In the severe work experiment the average heat output for twenty-four hours rose to 4.12 calories per kilogram and to 139.0 calories per square meter of body surface.

It is apparent, then, that the heat elimination, both per kilogram of body weight and per square meter of body surface, is in large part dependent upon the muscular activity of the subject, and it is therefore incorrect to compare experiments in which there is not some uniformity in the muscular activity. When allowance is made for these conditions the heat elimination per hour, on the basis of both body weight and body area, agrees closely for different experiments.

COMPARISON OF THE ELIMINATION OF CARBON DIOXID, WATER, AND HEAT FROM THE BODY AND THE INTAKE OF OXYGEN, PER DAY AND PER HOUR, PER KILOGRAM OF BODY WEIGHT.

The factors determined by the respiration calorimeter and recorded in the preceding tables permit of another comparison which is of special interest, since it has been the custom of some experimenters to compute the elimination of carbon dioxid in terms of liters per day and in terms of cubic centimeters per kilogram of body weight per hour. This has likewise been done for oxygen, and for purposes of comparison the values for water and heat should be included. Such data for the experiments here reported are given in Table 85, not only for the different experiments as a whole, but also for the different days of each experiment. The body weight of the subject is assumed to be the same during the entire experiment, an assumption which, however, is slightly erroneous. For example, in experiment No. 63, with a fat diet, the body weight of the subject (A. L. L.) did not remain constant at 73.4 kilograms. There was a steady loss of body weight during the whole experiment. For purposes of comparison, however, the variations in body weight were not taken into consideration. Since it is becoming more and more believed that the greatest factor influencing metabolism is the active mass of protoplasmic tissue, rather than the gross body weight, the assumption of a constant body weight here does not introduce a serious error, inasmuch as the losses in body weight experienced by the subject were in large part of fat, carbohydrates, and water, and not of protein.

Table 85.—*Elimination of carbon dioxid, water, and heat and intake of oxygen, per day and per hour, per kilogram of body weight.*

Experiment No.	Subject and kind of experiment.	Day.	Body weight.	Carbon dioxid.		Water.		Oxygen.		Heat.	
				Per day.	Per hour per kilogram.	Per day.	Per hour per kilogram.	Per day.	Per hour per kilogram.	Per day.	Per hour per kilogram.
	Rest experiments.		*Kgm.*	*Liters.*	*Cc.*	*Grams.*	*Gms.*	*Liters.*	*Cc.*	*Cal.*	*Cal.*
58	H. F., carbohydrate diet...	1	71.6	319.76	186.08	507.13	0.30	369.95	215.29	1,819.13	1.06
58	.....do.....................	2	71.6	328.14	190.96	828.78	.48	384.29	223.67	1,845.51	1.07
58	.....do.....................	3	71.6	359.56	209.24	816.94	.48	412.39	239.98	2,047.25	1.19
	Average per day.....	...	71.6	335.82	195.43	717.62	.42	388.88	226.30	1,903.96	1.11
60	B. F. D., carbohydrate diet.	1	66.7	392.35	245.10	959.54	.60	436.38	272.60	2,213.31	1.38
60	.....do.....................	2	66.7	387.59	242.12	272.15	.17	439.09	274.29	2,200.93	1.37
60	.....do.....................	3	66.7	411.23	256.89	1,198.69	.69	445.00	277.98	2,269.46	1.42
	Average per day.....	...	66.7	397.06	248.04	810.13	.49	440.16	274.96	2,227.90	1.39
65	A. L. L., carbohydrate diet.	1	72.5	414.94	238.47	1,072.46	.62	510.39	293.33	2,453.27	1.41
	Light exercise experiments.										
66	A. L. L., carbohydrate diet.	1	73.0	427.52	244.02	883.83	.50	494.91	282.48	2,470.54	1.41
67	.....do.....................	1	72.7	484.44	277.65	842.28	.48	553.72	317.35	2,654.96	1.52
67	.....do.....................	2	72.7	484.71	277.80	877.76	.50	558.52	320.11	2,721.93	1.56
	Average per day......	...	72.7	484.58	277.73	860.02	.49	556.12	318.73	2,688.45	1.54
	Work experiments.										
56	J. C. W., fat diet...........	1	75.9	903.96	496.25	3,702.27	2.03	1,081.67	593.80	5,295.10	2.91
56	.....do.....................	2	75.9	923.28	506.85	4,179.78	2.29	1,156.79	635.04	5,443.41	2.98
56	.....do.....................	3	75.9	864.15	474.40	3,907.14	2.14	1,062.46	583.26	5,123.88	2.81
	Average per day......	...	75.9	897.13	492.50	3,929.73	2.16	1,100.31	604.03	5,284.13	2.90
57	J. C. W., carbohydrate diet.	1	76.6	1,065.50	579.58	3,894.76	2.12	1,126.10	612.54	5,582.38	3.04
57	.....do.....................	2	76.6	1,012.50	550.75	4,191.47	2.28	1,094.00	595.09	5,377.72	2.94
57	.....do.....................	3	76.6	994.30	540.85	4,032.78	2.19	1,089.80	592.80	5,343.99	2.91
	Average per day......	...	76.6	1,024.10	557.06	4,039.67	2.20	1,103.30	600.13	5,434.70	2.96
61	B. F. D., carbohydrate diet.	1	67.0	814.36	506.44	2,869.45	1.78	916.35	569.87	4,565.03	2.84
62	A. L. L., carbohydrate diet.	1	75.4	863.40	477.12	3,415.85	1.89	960.18	530.60	4,802.30	2.65
62	.....do.....................	2	75.4	877.89	485.13	2,933.95	1.62	971.38	536.80	4,809.76	2.66
62	.....do.....................	3	75.4	866.50	478.84	3,573.19	1.97	979.49	541.27	4,852.31	2.68
	Average per day......	...	75.4	869.26	480.36	3,307.66	1.83	970.35	536.22	4,821.46	2.66
63	A. L. L., fat diet...........	1	73.4	815.42	462.88	3,952.69	2.24	986.22	559.84	4,946.74	2.81
63	.....do.....................	2	73.4	804.82	456.87	3,479.03	1.98	1,017.81	577.78	4,900.77	2.78
63	.....do.....................	3	73.4	803.58	456.16	3,653.96	2.07	1,018.05	577.91	4,822.58	2.74
	Average per day.....	...	73.4	807.94	458.64	3,695.22	2.10	1,007.36	571.84	4,890.03	2.78
64	A. L. L., fat diet...........	1	72.2	1,193.33	688.67	5,939.67	3.43	1,473.96	850.62	7,136.70	4.12

In experiment No. 58 there was, on the average, 195 cubic centimeters of carbon dioxid eliminated per hour per kilogram of body weight and a corresponding consumption of oxygen amounting to 226 cubic centimeters. There was a simultaneous elimination of 1.11 calories of heat per hour per kilogram of body weight. This was more nearly a "rest" experiment than any of the others here reported, i. e., the bodily activity of this subject was least of all. In the other rest experiments the consumption of oxygen and the elimination of carbon dioxid were larger, indeed in direct proportion to the increase in degree of muscular activity, the subject with light exercise demanding more than those at rest.

In the work experiments, the amounts of carbon dioxid eliminated and of oxygen absorbed per kilogram increased very noticeably, rising in the severe work experiment No. 64 to 688 cubic centimeters of carbon dioxid and 850 cubic centimeters of oxygen per kilogram per hour. This large respiratory exchange was accompanied by an elimination of 4.12 calories per kilogram of body weight per hour.

HEAT PRODUCTION.

The measurements of the amount of heat eliminated from the body during a given period are not necessarily the same as those of the amount of heat produced during that period. An increase or decrease in body weight or in body temperature during the period involves a corresponding increase or decrease in the amount of residual heat of the body. For example, when there has been an increase in body weight, the temperature of some substance has been raised from that at which it was taken into the body to that of the body. Or, if the weight has not changed, but the temperature of the body has risen, the total amount of heat in the body has been increased. Likewise, if there has been a loss of body weight, or of body temperature, the body no longer has stored in it so much heat as formerly. To determine the actual heat production, therefore, allowance must be made for the changes in the amount of heat residual in the body. For this reason, accurate determinations of the variations in body weight and body temperature are necessary.

MEASUREMENT OF BODY TEMPERATURE.

The variations in body temperature in some of these experiments were determined with great exactness by the use of a specially devised rectal-thermometer.[a] With this device measurements of temperature are based upon the variations in electrical resistance of a coil of fine copper wire, inclosed in a pure silver tube, and inserted in the rectum. The special form of Wheatstone bridge used for measurements of the temperature of the calorimeter is likewise used for the measurements of the rectal temperatures. The silver tube in the rectum gives the subject no discomfort, whether he is asleep or awake, thus insuring normal conditions. The measurements are made usually at intervals of 4 minutes.

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[a] Arch. Physiol. [Pflüger], 88 (1901), p. 492, and 90 (1902), p. 33.

In the rest experiments a continuous use of the rectal thermometer presents no special difficulties, and in experiments Nos. 58 and 60 observations with it were taken throughout the whole period. During the work experiments, however, although it has been possible for some subjects to wear the thermometer with no special discomfort, it was deemed inadvisable to jeopardize an experiment which was planned to continue six or more days by any possibility of local irritation by the use of the rectal thermometer during severe muscular work. At the conclusion of the work period in the series with A. L. L. the subject was disinclined to use the electrical thermometer, and its insertion was not insisted upon. Frequent observations were made, however, by means of a regular clinical thermometer.

In Table 86 are recorded the actual temperature observations by 3-hour periods, as measured in the two experiments in which the rectal thermometer was used. Usually temperature records are expressed in the form of a curve, and in previous discussions[a] of temperature measurements with this form of electrical thermometer, such curves were used. It is the purpose to report in detail elsewhere the temperature curves based upon the 4-minute observations. For the purpose of computing the heat production here under discussion, the temperatures at the end of 3-hour periods, as given below, are sufficient.

TABLE 86.—*Summary of body temperatures by 3-hour periods, as shown by measurements with the rectal thermometer.*

Time.	Period preliminary to experiment No. 58.	Experiment No. 58.			Period preliminary to experiment No. 60.	Experiment No. 60.		
		Nov. 10-11.	Nov. 11-12.	Nov. 12-13.		Jan. 27-28.	Jan. 28-29.	Jan. 29-30.
	°C.	*°C.*	*°C.*	*°C.*	*°C.*	*°C.*	*°C.*	*°C.*
7 a. m.	....	36.71	....	....	....	36.48	....	....
10 a. m.	....	36.74	37.23	37.54	....	36.78	36.68	36.70
1 p. m.	....	36.98	37.14	37.69	....	36.55	36.56	36.66
4 p. m.	....	37.07	37.55	37.80	....	36.44	36.55	36.61
7 p. m.	....	36.94	37.83	37.90	....	35.99	36.61	36.92
10 p. m.	....	37.17	37.93	38.23	....	36.26	36.50	36.64
1 a. m.	36.58	36.99	37.90	37.88	36.20	36.10	36.12	36.28
4 a. m.	36.72	36.98	37.57	37.72	36.14	36.24	36.23	36.29
7 a. m.	36.71	36.29	37.67	37.81	36.48	36.71	36.60	36.69

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[a] Arch. Physiol. [Pflüger], 90 (1902), p. 33, and Amer. Jour. Physiol., 11 (1904), p. 145.

In experiment No. 58 the temperature of the subject gradually increased during the three days of the experiment. The exact cause of this increase is not known. We have reason to believe, however, that the highest temperatures recorded were not actually as high as they appear, owing to alterations in the electrical connections. Since, however, the temperature differences, rather than the absolute temperatures, were of importance in this investigation, it was deemed inadvisable to have the thermometer removed and recalibrated during the experiment. Observations of pulse rate and occasional tests with the clinical thermometer failed to indicate any abnormal rise in temperature with this subject.

In experiment No. 60 the temperature observations we believe to be absolutely as recorded, since the electrical connections were perfected and the thermometer carefully calibrated both before and after the experiment. It is important to bear in mind, however, that the significance of these temperature observations is rather in the fluctuations than the absolute values.

Fluctuations in Body Temperature.

Contrary to popular impression, the temperature of the body is not fixed at 98.4° F., which is usually marked on the clinical thermometer as ''normal.'' A number of factors modify it, among which may be mentioned ingestion of food, body activity, and body position. Aside from these more or less definite causes for fluctuations in body temperature there is a regular daily rhythm, which is in a large measure entirely independent of muscular activity. The rhythm is characterized by a minimum temperature between the hours of 3 and 5 a. m., a marked rise during the early morning, which continues, but more slowly, during the forenoon and early afternoon to a maximum at about 4 p. m. and an evening fall. The fluctuations during different periods of the day in experiments Nos. 58 and 60 are recorded in Table 87. These data are used as subsequently explained for computing the gain or loss of body heat due to rise or fall of the temperature of the body.

TABLE 87.—*Summary of changes of body temperature for 3-hour periods, as shown by measurements with rectal thermometer—Rise (+) and fall (−).*

Time.	Experiment No. 58.			Experiment No. 60.		
	Nov. 10–11.	Nov. 11–12.	Nov. 12–13.	Jan. 27–28.	Jan. 28–29.	Jan. 29–30.
	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*
7 a. m.						
10 a. m.	+0.03	+0.94	−0.13	+0.30	−0.03	+0.10
1 p. m.	+ .24	− .09	+ .15	− .23	− .12	− .04
Total, 6 hours	+ .27	+ .85	+ .02	+ .07	− .15	+ .06
4 p. m.	+ .09	+ .41	+ .11	− .11	− .01	− .05
7 p. m.	− .13	+ .28	+ .10	− .45	+ .06	+ .31
Total, 6 hours	− .04	+ .69	+ .21	− .56	+ .05	+ .26
Total, 12 hours	+ .23	+1.54	+ .23	− .49	− .10	+ .32
10 p. m.	+ .23	+ .10	+ .33	+ .27	− .11	− .28
1 a. m.	− .18	− .03	− .35	− .16	− .38	− .36
Total, 6 hours	+ .05	+ .07	− .02	+ .11	− .49	− .64
4 a. m.	− .01	− .33	− .16	+ .14	+ .11	+ .01
7 a. m.	− .69	+ .10	+ .09	+ .47	+ .37	+ .40
Total, 6 hours	− .70	− .23	− .07	+ .61	+ .48	+ .41
Total, 12 hours	− .65	− .16	− .09	+ .72	+ .01	− .23
Total, 24 hours	− .42	+1.38	+ .14	+ .23	− .09	+ .09

DETERMINATIONS OF BODY WEIGHT.

It was long deemed desirable to have inside the respiration chamber some device by which the subject could be weighed accurately. Indeed, the study of the income and outgo of material in the body is not satisfactory without a true record of body weight. The first attempt to secure such records was made by means of a small platform balance, a so-called silk scale sensitive to 10 grams, placed inside the respiration chamber, upon which the subject weighed himself. The floor of the calorimeter chamber, however, was far from level, and this made it extremely difficult to center the balance and adjust it so that it would always weigh under uniform conditions. Furthermore, even skilled and accurate subjects would occasionally make gross errors in the weighings, which there was practically no method of correcting.

After a number of years' experience with this method of weighing, which convinced us of its inaccuracy for experiments of this nature, an apparatus[a] was devised by which the weighings could be made and checked by observers outside. To accomplish this, a small hole was cut through the ceiling of the respiration chamber and a tube fitted to it which extended up through the floor into the room above. The balance was then placed on proper supports and a framework suspended on the platform of it so that a rod passing up through the tube could be attached to the yoke. On the lower end of this rod the chair in which the subject sits can be suspended. A flexible rubber diaphragm was attached to the rod and to the tube in such a way that a leakage of air was prevented, while the sensitiveness of the balance was in nowise affected. As the stress was all directly downward, two guide rods which were attached to the underside of the platform of the balance, to prevent excessive lateral motion, could be removed, and thereby its sensitiveness was much increased.

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[a] Carnegie Inst. Washington Pub. No. 40, p. 158.

Numerous tests with the balance have shown that the weight of a man's body can be ascertained accurately to within 2 or 3 grams. Indeed, the accuracy is so great that it is necessary to record the exact hour and minute at which the weighing is made, because the continual loss by respiration and perspiration is such that a delay of three or four minutes will result in an erroneous weight. The apparatus has been frequently checked by having the subject sit in the swinging chair, bringing the whole system into equilibrium, and then placing in the lap of the subject brass weights of different values. The observer on the floor above has then made the weighings and determined the gain of weight thus added. The agreement is in all cases very satisfactory.

This device was installed previous to the beginning of experiment No. 62, and has been used in all experiments since, the subject being weighed each morning at 7. At the present time there is no difficulty in weighing a subject accurately, but some experience was necessary before reliable data regarding changes in body weight could be obtained with it. Precautions must be taken to see that the changes in underclothing, the drinking of water, and the collection of urine and feces are carried out in such a way as to allow proper corrections, as otherwise the great accuracy of the balance is of no avail.

The device is used for weighing not only the subject himself, but his clothing, bedding, books, and all articles in the chamber that are weighed. Even the heat absorbers are now attached to the rod suspended from the balance and weighed by the observers outside the chamber.

The weights of the subjects in the different experiments are recorded in Table 122 of the Appendix

ESTIMATION OF CORRECTIONS FOR CHANGES IN BODY TEMPERATURES AND BODY WEIGHT.

The correction for the amount of heat involved in the variations in body temperature and body weight is computed from the data regarding the weight and temperature fluctuations obtained as previously explained and the specific heat of the body. For this latter factor Pembrey's[a] estimate of 0.83 is used, as it is believed to be not far from the true value. Since either factor, weight or temperature, may remain constant while the other increases or diminishes, or both may fluctuate in the same or in opposite directions, there are six possibilities for variation in the amount of heat residual in the body. Whatever the conditions, however, the result may be computed by the use of the following formula: [(initial body temperature − 20°) × (initial body weight × 0.83) − (final body temperature − 20°) × (final body weight × 0.83)]. Thus, if a subject weighing 60 kilograms neither gains nor loses weight, but has a temperature 1° higher at the end of a period than at the beginning, the amount of heat residual in the body will have been increased during the period by about 50 calories.

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[a] Schaefer's Text-book of Physiology (1898), Vol. I, p. 839.

In the case of gain in weight by the body, the material that has been added has been warmed from the temperature of the calorimeter chamber, i. e., 20° C., to that of the body. Drinking water and milk are usually introduced into the respiration chamber at a temperature much below 20°, but correction for the heat absorbed by these materials in acquiring the temperature of the chamber is made in another place, and also for the cooling of hot drinks, as tea or coffee, placed in the chamber.

The influence of the change in body temperature upon the heat elimination is greatest during the night periods when the total amount of heat eliminated is naturally small. The corrections due to change in body weight are of most importance when body material is being either added to or consumed. A loss of body material may result from an entire withdrawal of food, as in fasting experiments, or from insufficient diet in ordinary experiments, as during periods of severe muscular work. Because the output of heat during the period of work is large, the correction for heat involved in change of body weight is proportionately much less significant than in the case in which the loss in body weight is due to fasting, for in general during fasting the heat output is at a minimum. In any case, in order to secure an accurate estimate of the heat production for a given period, corrections must be made for the fluctuation in body temperature and in body weight. Even in rest experiments, the changes in body temperature for a given period may amount to 1° C. or so, as shown in Table 87.

COMPUTATION FROM GAIN OR LOSS OF BODY MATERIAL.

Variations in body weight are due to gains and losses of body material and water. The data obtained with the new form of respiration apparatus afford means for computing the gains or losses of these materials, and, theoretically at least, it would be more accurate to compute the changes in amount of residual heat in the body from these various substances and the specific heat of each, than to assume, as has thus far been done, that the average specific heat of the total material gained or lost is that of the body as a whole. Indeed in experiments in which the records of body weight show obvious error, this method is followed. The data given in Table 88 for a 24-hour period in experiment No. 60 may be used in illustration of such computation.

TABLE 88.—*Data for computing quantity of heat gained or lost to the body in change of weight and temperature.*

Subject and character of experiment.	Time.	Actual body weight	Actual body temperature by rectal thermometer.	Gain (+) or loss (−) of body temperature.	Gain (+) or loss (−) of body protein.	Gain (+) or loss (−) of body fat.	Gain (+) or loss (−) of body carbohydrates.	Gain (+) or loss (−) of body water.	Correction due to change of body temperature and body weight
Experiment No. 60, with B. F. D., carbohydrate diet:		*Kgms.*	°*C.*	°*C.*	*Gms.*	*Grams.*	*Grams.*	*Grams.*	*Cals.*
Jan. 29	7 a. m.	67.43	36.61						
Jan. 30	7 a. m.	67.31	36.67	+0.06	−3.90	+30.19	−42.25	−567.17	−5.887

In this experiment the subject ascertained his own body weight by use of a platform balance within the chamber. According to the records made at the beginning and end of this period, there was a loss of 0.12 kilogram in total weight, but this is manifestly incorrect, because according to the balance of income and outgo of matter in the body there was a loss of 3.9 grams of protein, 42.25 grams of carbohydrates, and 657.17 grams of water from the body, and a gain of only 30.19 grams of fat.

The weight of the body at the beginning of the period multiplied by the specific heat, and this product by the rise in temperature, would give the amount of heat added to the residual if there had been no change of weight, but this value must be corrected by the quantity of heat in the gain or loss of the materials mentioned. For the first step the hydrothermal equivalent of each material is computed from its amount (in kilograms) and its specific heat, the specific heat of protein and fat being quoted from Schaefer[a] and that of carbohydrate from data by Kopp and Hess reported by Landott and Bernstein.[b] The algebraic sum of these equivalents is next multiplied by the difference between the temperature of the calorimeter (which was 20.2° for this period) and that of the body at the end of the period. The latter product is then subtracted from that obtained from the data for body weight and temperature, mentioned above. These steps are indicated by the following formula: $(67.43 \times 0.83 \times 0.06) - [\{(0.0039 \times 0.74) + (0.0425 \times 0.3) + (0.56717 \times 1) - (0.03019 \times 0.71)\} \times (36.67 - 20.20)] = 5.887$.

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[a] Text-book of Physiology (1898), Vol. I, p. 839.

[b] "Physik Tabellen," 1905, p. 330.

The result is the number of calories for which correction should be made, because of changes in body temperature and in the store of body materials and water. In this case the quantity is negative, which means that it is to be subtracted from the measurement of heat eliminated during the period.

With correct data regarding the changes in total body weight there is less necessity for computing the fluctuations in residual heat from the amounts of body materials gained or lost; but when, as in experiment No. 60, for example, the methods for determining body weight were unsatisfactory, this method of computation at least gives some indication of the probable error. It so happens that with the small quantity of heat measured in this experiment an error of 6 calories is not inconsiderable.

CORRECTIONS FOR HEAT ABSORBED BY BED AND BEDDING.

Another correction which should be applied in determining the actual heat production in short periods is that for the amount of heat involved in the warming and cooling of the bed and bed clothing. When the subject retires, the bed and bedding are at the temperature of the calorimeter chamber, but they are soon warmed to approximately 30°, the heat being derived from the man's body, consequently a smaller amount of heat is measured for this period than is actually produced. Similarly when he arises, the warm bed clothing gives off heat until it is cooled again to the temperature of the respiration chamber, and the amount of heat measured during this period is larger than that actually produced. Inasmuch as the subject retires at 11 p. m. and rises at 7 a. m., the heat measurement for the period from 11 p. m. to 1 a. m. is invariably too small and that for the period from 7 a. m. to 10 a. m. is invariably too large. Since the bedding is both warmed and cooled in each twenty-four hours, the values are balanced each day and the total heat determination for the day is not affected, but some correction is necessary for the measurement by periods during the hours mentioned.

The difficulties in making this correction have been previously explained.[a] As a result of tentative estimation, it has been assumed in previous discussions that 30 calories are absorbed by the bedding in the period in which the subject retires, and the same amount liberated in the period in which he arises. Experiments to determine the actual amount of heat involved had not given very satisfactory results at the time the present investigations were made, consequently the same factor has been employed here also. It seems probable that this tentative correction is not far from the true one, but it is hoped that later investigation will give more accurate knowledge concerning it.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 157.

TOTAL HEAT PRODUCTION.

Data regarding the heat production as compared with the heat elimination in the experiments reported in the present bulletin are summarized in Table 89. The table also shows the figures for the carbon dioxid thermal quotient, but these are given here simply for convenience; they are discussed in the subsequent section.

TABLE 89.—*Amount of heat produced, and ratio of heat to carbon dioxid.*

Date.	Period.	(a) Rise (+) or fall (−) of body temperature.	(b) Gain (+) or loss (−) of body heat (0.83$a \times w$).	(c) Assumed correction for bed and bedding.	(d) Heat eliminated, measured.	(e) Amount of heat produced, $b+c+d$.	(f) Carbon dioxid eliminated.	(g) Carbon dioxid per 100 calories of energy, $100f \div e$.
	REST EXPERIMENTS.							
	Experiment No. 58, with H. F., carbohydrate diet.							
1903.		°C	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Grams.*
Nov. 10–11	7 a. m. to 1 p. m...........	+0.27	+16.0	−30	392.3	378.3	132.8	35.1
	1 p. m. to 7 p. m...........	− .04	− 2.4	....	543.8	541.4	187.0	34.5
	Total, 12 hours......	+ .23	+13.6	−30	936.1	919.7	319.8	34.8
	7 p. m. to 1 a. m...........	+ .05	+ 3.0	+30	482.2	515.2	168.4	32.7
	1 a. m. to 7 a. m...........	− .70	−41.6	....	400.8	359.2	139.9	38.9
	Total, 12 hours......	− .65	−38.6	+30	883.0	874.4	308.3	35.3
	Total, 24 hours......	− .42	−25.0	....	1,819.1	1,794.1	628.1	35.0
Nov. 11–12	7 a. m. to 1 p. m...........	+ .85	+50.5	−30	563.7	584.2	160.5	27.5
	1 p. m. to 7 p. m...........	+ .69	+41.0	....	423.9	464.9	179.5	38.6
	Total, 12 hours......	+1.54	+91.5	−30	987.6	1,049.1	340.0	32.4
	7 p. m. to 1 a. m...........	+ .07	+ 4.2	+30	434.5	468.7	168.0	35.8
	1 a. m. to 7 a. m...........	− .23	−13.7	....	423.4	409.7	136.5	33.3
	Total, 12 hours......	− .16	− 9.5	+30	857.9	878.4	304.5	34.7
	Total, 24 hours......	+1.38	+82.0	....	1,845.5	1,927.5	644.5	33.4
Nov. 12–13	7 a. m. to 1 p. m...........	+ .02	+ 1.2	−30	611.1	582.3	184.2	31.6
	1 p. m. to 7 p. m...........	+ .21	+12.5	....	527.5	540.0	206.4	38.2
	Total, 12 hours......	+ .23	+13.7	−30	1,138.6	1,122.3	390.6	34.8
	7 p. m. to 1 a. m...........	− .02	− 1.2	+30	465.7	494.5	171.5	34.7
	1 a. m. to 7 a. m...........	− .07	− 4.1	....	443.0	438.9	144.2	32.9
	Total, 12 hours......	− .09	− 5.3	+30	908.7	933.4	315.7	33.8
	Total, 24 hours......	+ .14	+ 8.3	....	2,047.3	2,055.7	706.3	34.4
	Experiment No. 60, with B. F. D., carbohydrate diet.							
1904. Jan. 27–28	7 a. m. to 10 a. m..........	+ .30	+16.6	−30	355.4	342.0	126.7	37.1
	10 a. m. to 1 p. m..........	− .23	−12.7	....	292.6	279.9	97.5	34.8
	Total, 6 hours.......	+ .07	+ 3.9	−30	648.0	621.9	224.2	36.1
	1 p. m. to 4 p. m...........	− .11	− 6.1	....	301.0	294.9	107.0	36.3
	4 p. m. to 7 p. m...........	− .45	−24.9	....	293.0	268.1	98.7	36.8
	Total, 6 hours.......	− .56	−31.0	....	594.0	563.0	205.7	36.5
	Total, 12 hours......	− .49	−27.1	−30	1,242.0	1,184.9	429.9	36.3
	7 p. m. to 10 p. m..........	+ .27	+14.9	....	325.1	340.0	119.6	35.2
	10 p. m. to 1 a. m..........	− .16	− 8.9	+30	238.9	260.0	84.5	32.5
	Total, 6 hours.......	+ .11	+ 6.0	+30	564.0	600.0	204.1	34.0

TABLE 89.—*Amount of heat produced, and ratio of heat to carbon dioxid*—Continued.

Date.	Period.	(*a*) Rise (+) or fall (−) of body temperature.	(*b*) Gain (+) or loss (−) of body heat (0.83*a*× *w*).	(*c*) Assumed correction for bed and bedding.	(*d*) Heat eliminated, measured.	(*e*) Amount of heat produced, *b*+*c*+*d*.	(*f*) Carbon dioxid eliminated.	(*g*) Carbon dioxid per 100 calories of energy, 100*f*÷*e*.
	REST EXPERIMENTS—Con.							
	Experiment No. 60, with B. F. D., carbohydrate diet—Continued.							
1904.		° *C.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Grams.*
Jan. 27-28	1 a. m. to 4 a. m	+0.14	+ 7.8	....	203.1	210.9	63.9	30.3
	4 a. m. to 7 a. m	+ .47	+26.0	....	204.2	230.2	72.8	31.6
	Total, 6 hours	+ .61	+33.8	....	407.3	441.1	136.7	31.0
	Total, 12 hours	+ .72	+39.8	+30	971.3	1,041.1	340.8	32.7
	Total, 24 hours	+ .23	+12.7	....	2,213.3	2,226.0	770.7	34.6
Jan. 28	7 a. m. to 10 a. m	− .03	− 1.7	−30	367.7	336.0	124.9	37.2
	10 a. m. to 1 p. m	− .12	− 6.6	....	303.9	297.3	102.7	34.5
	Total, 6 hours	− .15	− 8.3	−30	671.6	633.3	227.6	35.9
	1 p. m. to 4 p. m	− .01	− .5	....	302.2	301.7	108.6	36.0
	4 p. m. to 7 p. m	+ .06	+ 3.3	....	298.2	301.5	99.5	33.0
	Total, 6 hours	+ .05	+ 2.8	....	600.4	603.2	208.1	34.5
	Total, 12 hours	− .10	− 5.5	−30	1,272.0	1,236.5	435.7	35.3
	7 p. m. to 10 p. m	− .11	− 6.1	....	344.9	338.8	126.9	37.5
	10 p. m. to 1 a. m	− .38	−21.0	+30	218.8	227.8	70.9	31.1
	Total, 6 hours	− .49	−27.1	+30	563.7	566.6	197.8	34.9
	1 a. m. to 4 a. m	+ .11	+ 6.0	....	184.7	190.7	64.1	33.6
	4 a. m. to 7 a. m	+ .37	+20.5	....	180.5	201.0	63.8	31.7
	Total, 6 hours	+ .48	+26.5	....	365.2	391.7	127.9	32.7
	Total, 12 hours	− .01	− .6	+30	928.9	958.3	325.7	34.0
	Total, 24 hours	− .11	− 6.1	....	2,200.9	2,194.8	761.4	34.7
Jan. 29	7 a. m. to 10 a. m	+ .10	+ 5.5	−30	376.6	352.1	118.5	33.7
	10 a. m. to 1 p. m	− .04	− 2.2	....	317.0	314.8	116.3	36.9
	Total, 6 hours	+ .06	+ 3.3	−30	693.6	666.9	234.8	35.2
	1 p. m. to 4 p. m	− .05	− 2.8	....	310.0	307.2	113.7	37.0
	4 p. m. to 7 p. m	+ .31	+17.2	....	317.3	334.5	123.5	36.9
	Total, 6 hours	+ .26	+14.4	....	627.3	641.7	237.2	37.0
	Total, 12 hours	+ .32	+17.7	−30	1,320.9	1,308.6	472.0	36.1
	7 p. m. to 10 p. m	− .28	−15.5	....	338.2	322.7	118.8	36.8
	10 p. m. to 1 a. m	− .36	−19.9	+30	229.5	239.6	82.6	34.5
	Total, 6 hours	− .64	−35.4	+30	567.7	562.3	201.4	35.8
	1 a. m. to 4 a. m	+ .01	+ .6	....	195.0	195.6	64.9	33.2
	4 a. m. to 7 a. m	+ .40	+22.1	....	185.9	208.0	69.5	33.4
	Total, 6 hours	+ .41	+22.7	....	380.9	403.6	134.4	33.3
	Total, 12 hours	− .23	−12.7	+30	948.6	965.9	335.8	34.8
	Total, 24 hours	+ .09	+ 5.0	....	2,269.5	2,274.5	807.8	35.5
	Experiment No. 65, with A. L. L., carbohydrate diet.							
Apr. 23-24	7 a. m. to 10 a. m	....	....	−30	337.7	....	113.1	....
	10 a. m. to 1 p. m	....	....	....	295.6	....	86.0	....
	Total, 6 hours	−.34	−20.5	−30	633.3	582.8	199.1	31.2

TABLE 89.—*Amount of heat produced, and ratio of heat to carbon dioxid*—Continued.

Date.	Period.	(*a*) Rise (+) or fall (−) of body temperature.	(*b*) Gain (+) or loss (−) of body heat (0.83*a*× *w*).	(*c*) Assumed correction for bed and bedding.	(*d*) Heat eliminated, measured.	(*e*) Amount of heat produced. *b*+*c*+*d*.	(*f*) Carbon dioxid eliminated.	(*g*) Carbon dioxid per 100 calories of energy, 100*f*÷*e*.
	REST EXPERIMENTS—Con.							
	Experiment No. 65, with A. L. L., carbohydrate diet—Continued.							
1904.		°*C.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Grams.*
Apr. 23–24	1 p. m. to 4 p. m	....	....	....	293.1	....	110.5	....
	4 p. m. to 7 p. m	....	....	....	336.5	....	96.5	....
	Total, 6 hours	−0.16	− 9.6	....	629.6	620.0	207.0	33.4
	Total, 12 hours	− .50	−30.1	−30	1,262.9	1,202.8	406.1	33.8
	7 p. m. to 10 p. m	+ .05	+ 3.0	....	337.6	340.6	119.9	....
	10 p. m. to 1 a. m	....	....	+30	343.2	....	126.8	....
	Total, 6 hours	....	....	+30	680.8	....	246.7	....
	1 a. m. to 4 a. m	....	....	....	261.2	....	84.9	....
	4 a. m. to 7 a. m	....	....	....	248.4	....	77.4	....
	Total, 6 hours	....	....	....	509.6	....	162.3	....
	Total, 12 hours	+ .11	+ 6.6	+30	1,190.4	1,227.0	409.0	33.3
	Total, 24 hours	− .39	−23.5	....	2,453.3	2,429.8	815.0	33.5
	Experiment No. 66, with A. L. L., carbohydrate diet.							
Apr. 24–25	7 a. m. to 10 a. m	− .39	−23.6	−30	401.8	342.8	130.3	37.4
	10 a. m. to 1 p. m	....	....	....	348.5	....	119.0	....
	Total, 6 hours	....	....	−30	750.3	....	249.3	....
	1 p. m. to 4 p. m	....	....	....	328.8	....	113.7	....
	4 p. m. to 7 p. m	− .28	−17.0	....	338.6	321.6	118.6	36.9
	Total, 6 hours	....	....	....	667.4	....	232.3	....
	Total, 12 hours	− .61	−37.0	−30	1,417.7	1,350.7	481.6	35.7
	7 p. m. to 10 p. m	+ .11	+ 6.7	....	309.2	315.9	107.2	33.9
	10 p. m. to 1 a. m	....	....	+30	246.1	....	97.1	....
	Total, 6 hours	....	....	+30	555.3	....	204.3	....
	1 a. m. to 4 a. m	....	....	....	244.2	....	74.6	....
	4 a. m. to 7 a. m	....	....	....	253.3	....	79.2	....
	Total, 6 hours	....	....	....	497.5	....	153.8	....
	Total, 12 hours	+ .22	+13.3	+30	1,052.8	1,096.1	358.1	32.7
	Total, 24 hours	− .39	−23.6	....	2,470.5	2,446.9	839.7	34.3
	Experiment No. 67, with A. L. L., carbohydrate diet.							
Apr. 25–26	7 a. m. to 10 a. m	+ .17	+10.3	−30	433.5	413.8	150.1	36.3
	10 a. m. to 1 p. m	− .17	−10.3	....	401.3	391.0	138.3	35.4
	Total, 6 hours	....	....	−30	834.8	804.8	288.4	35.8
	1 p. m. to 4 p. m	+ .39	+23.5	....	362.6	386.1	137.4	35.6
	4 p. m. to 7 p. m	− .06	− 3.6	....	397.6	394.0	138.7	35.2
	Total, 6 hours	+ .33	+19.9	....	760.2	780.1	276.1	35.4
	Total, 12 hours	+ .33	+19.9	−30	1,595.0	1,584.9	564.5	35.6
	7 p. m. to 10 p. m	....	....	....	322.3	322.3	117.9	36.6
	10 p. m. to 1 a. m	....	....	+30	278.6	....	115.1	....
	Total, 6 hours	....	....	+30	600.9	....	233.0	....

TABLE 89.—*Amount of heat produced, and ratio of heat to carbon dioxid*—Continued.

Date.	Period.	(*a*) Rise (+) or fall (−) of body temperature.	(*b*) Gain (+) or loss (−) of body heat (0.83*a*× *w*).	(*c*) Assumed correction for bed and bedding.	(*d*) Heat eliminated, measured.	(*e*) Amount of heat produced, *b*+*c*+*d*.	(*f*) Carbon dioxid eliminated.	(*g*) Carbon dioxid per 100 calories of energy, 100*f*÷*e*.
	REST EXPERIMENTS—Con.							
	Experiment No. 67, with A. L. L., carbohydrate diet—Continued.	°*C.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Grams.*
1904. Apr. 25–26	1 a. m. to 4 a. m				241.6		78.3	
	4 a. m. to 7 a. m				217.5		75.7	
	Total, 6 hours				459.1		154.0	
	Total, 12 hours	−0.16	− 9.7	+30	1,060.0	1,080.3	387.0	35.8
	Total, 24 hours	+ .17	+10.3		2,655.0	2,665.3	951.5	35.7
Apr. 26–27	7 a. m. to 10 a. m	+ .27	+16.3	−30	456.2	442.5	155.8	35.2
	10 a. m. to 1 p. m				421.1		136.9	
	Total, 6 hours			−30	877.3		292.7	
	1 p. m. to 4 p. m				438.2		165.4	
	4 p. m. to 7 p. m				383.7		132.5	
	Total, 6 hours				821.9		297.9	
	Total, 12 hours			−30	1,699.2		590.6	
	7 p. m. to 10 p. m				303.6		112.1	
	10 p. m. to 1 a. m			+30	268.8		101.8	
	Total, 6 hours			+30	572.4		213.9	
	1 a. m. to 4 a. m				235.0		73.3	
	4 a. m. to 7 a. m				215.3		74.3	
	Total, 6 hours				450.3		147.6	
	Total, 12 hours			+30	1,022.7		361.5	
	Total, 24 hours	+ .05	+ 3.0		2,721.9	2,724.9	952.1	34.9
	WORK EXPERIMENTS.							
	Experiment No. 56, with J. C. W., fat diet.							
Apr. 27–28	7 a. m. to 1 p. m	+ .67	+42.2	−30	2,003.7	2,015.9	693.7	34.4
	1 p. m. to 7 p. m				1,985.6		680.9	
	Total, 12 hours			−30	3,989.3		1,374.6	
	7 p. m. to 1 a. m			+30	777.9		237.7	
	1 a. m. to 7 a. m				527.9		163.3	
	Total, 12 hours			+30	1,305.8		401.0	
	Total, 24 hours	− .55	−34.6		5,295.1	5,260.5	1,775.6	33.8
Apr. 28–29	7 a. m. to 1 p. m			−30	2,203.0		754.3	
	1 p. m. to 7 p. m				1,966.1		654.2	
	Total, 12 hours			−30	4,169.1		1,408.5	
	7 p. m. to 1 a. m			+30	737.2		239.6	
	1 a. m. to 7 a. m				527.1		165.5	
	Total, 12 hours			+30	1,264.3		405.1	
	Total, 24 hours	+ .39	+24.6		5,433.4	5,458.0	1,813.6	33.2
Apr. 29–30	7 a. m. to 1 p. m			−30	1,852.5		618.2	
	1 p. m. to 7 p. m				2,011.5		684.1	
	Total, 12 hours			−30	3,864.0		1,302.3	

Table 89.—*Amount of heat produced, and ratio of heat to carbon dioxid*—Continued.

Date.	Period.	(*a*) Rise (+) or fall (−) of body temperature.	(*b*) Gain (+) or loss (−) of body heat (0.83*a*× *w*).	(*c*) Assumed correction for bed and bedding.	(*d*) Heat eliminated, measured.	(*e*) Amount of heat produced, *b*+*c*+*d*.	(*f*) Carbon dioxid eliminated.	(*g*) Carbon dioxid per 100 calories of energy, 100*f*÷*e*.
	Work Experiments—Con.							
	Experiment No. 56, with J. C. W., fat diet—Con.							
1904.		*°C.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Grams.*
Apr. 29–30	7 p. m. to 1 a. m			+30	726.3		232.8	
	1 a. m. to 7 a. m				533.6		162.3	
	Total, 12 hours			+30	1,259.9		395.1	
	Total, 24 hours	−0.11	− 6.9		5,123.9	5,117.0	1,697.4	33.2
	Experiment No. 57, with J. C. W., carbohydrate diet.							
May 7–8	7 a. m. to 1 p. m			−30	2,225.4		852.3	
	1 p. m. to 7 p. m				2,120.1		781.6	
	Total, 12 hours	− .11	− 7.0	−30	4,345.5	4,308.5	1,633.9	37.9
	7 p. m. to 1 a. m			+30	762.2		281.1	
	1 a. m. to 7 p. m				474.7		177.9	
	Total, 12 hours	+ .27	+17.2	+30	1,236.9	1,284.1	459.0	35.7
	Total, 24 hours	+ .16	+10.2		5,582.4	5,592.6	2,092.9	37.4
May 8–9	7 a. m. to 1 p. m	+ .34	+21.6	−30	1,964.4	1,956.0	723.3	37.0
	1 p. m. to 7 p. m	+ .16	+10.2		2,089.8	2,100.0	784.7	37.4
	Total, 12 hours	+ .50	+31.8	−30	4,054.2	4,056.0	1,508.0	37.2
	7 p. m. to 1 a. m			+30	820.9		306.3	
	1 a. m. to 7 a. m				502.6		174.5	
	Total, 12 hours	− .61	−38.8	+30	1,323.5	1,314.7	480.8	36.6
	Total, 24 hours	− .11	− 7.0		5,377.7	5,370.7	1,988.8	37.0
May 9–10	7 a. m. to 1 p. m			−30	2,486.9		909.2	
	1 p. m. to 7 p. m				1,649.3		598.5	
	Total, 12 hours	+ .39	+24.8	−30	4,136.2	4,131.0	1,507.7	36.5
	7 p. m. to 1 a. m			+30	721.0		271.2	
	1 a. m. to 7 a. m				486.8		174.1	
	Total, 12 hours	− .44	−28.0	+30	1,207.8	1,209.8	445.3	36.8
	Total, 24 hours	− .05	− 3.2		5,344.0	5,340.8	1,953.0	36.6
	Experiment No. 61, with B. F. D., carbohydrate diet.							
1905. Jan. 30–31	7 a. m. to 10 a. m			−30	902.5		363.7	
	10 a. m. to 1 p. m				1,084.5		396.5	
	Total, 6 hours			−30	1,987.0		760.2	
	1 p. m. to 4 p. m				790.4		267.5	
	4 p. m. to 7 p. m				673.2		211.1	
	Total, 6 hours				1,463.6		478.6	
	Total, 12 hours			−30	3,450.6		1,238.8	
	7 p. m. to 10 p. m				361.0		118.0	
	10 p. m. to 1 a. m			+30	253.6		89.7	
	Total, 6 hours			+30	614.6		207.7	

Table 89.—*Amount of heat produced, and ratio of heat to carbon dioxid*—Continued.

Date.	Period.	(*a*) Rise (+) or fall (−) of body temperature.	(*b*) Gain (+) or loss (−) of body heat (0.83*a*× *w*).	(*c*) Assumed correction for bed and bedding.	(*d*) Heat eliminated, measured.	(*e*) Amount of heat produced, *b*+*c*+*d*.	(*f*) Carbon dioxid eliminated.	(*g*) Carbon dioxid per 100 calories of energy, 100*f*÷*e*.
	Work Experiments—Con.							
	Experiment No. 61, with B. F. D., carbohydrate diet—Continued.							
1905.		° *C.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Grams.*
Jan. 30–31	1 a. m. to 4 a. m				261.7		82.5	
	4 a. m. to 7 a. m				238.1		70.6	
	Total, 6 hours				499.8		153.1	
	Total, 12 hours			+30	1,114.4		360.8	
	Total, 24 hours				4,565.0		1,599.6	
	Experiment No. 62, with A. L. L., carbohydrate diet.							
Apr. 16–17	7 a. m. to 10 a. m			−30	890.5		337.5	
	10 a. m. to 1 p. m				932.6		311.7	
	Total, 6 hours			−30	1,823.1		649.2	
	1 p. m. to 4 p. m				877.7		319.6	
	4 p. m. to 7 p. m				927.8		323.7	
	Total, 6 hours				1,805.5		643.3	
	Total, 12 hours			−30	3,628.6		1,292.5	
	7 p. m. to 10 p. m				356.3		113.9	
	10 p. m. to 1 a. m			+30	331.1		114.5	
	Total, 6 hours			+30	687.4		228.4	
	1 a. m. to 4 a. m				257.5		94.4	
	4 a. m. to 7 a. m				228.8		80.6	
	Total, 6 hours				486.3		175.0	
	Total, 12 hours			+30	1,173.7		403.4	
	Total, 24 hours				4,802.3		1,695.9	
Apr 17–18	7 a. m. to 10 a. m			−30	931.1		342.3	
	10 a. m. to 1 p. m	−0.77	−48.2		955.2	907.0	332.9	36.7
	Total, 6 hours			−30	1,886.3		675.2	
	1 p. m. to 4 p. m	+ .61	+38.2		852.4	890.6	322.3	36.2
	4 p. m. to 7 p. m	− .28	−17.5		869.1	851.6	314.7	
	Total, 6 hours	+ .33	+20.7		1,721.5	1,742.2	637.0	36.6
	Total, 12 hours			−30	3,607.8		1,312.2	
	7 p. m. to 10 p. m				367.9		138.9	
	10 p. m. to 1 a. m			+30	317.3		107.8	
	Total, 6 hours			+30	685.2		246.7	
	1 a. m. to 4 a. m				266.3		81.8	
	4 a. m. to 7 a. m				250.5		83.7	
	Total, 6 hours				516.8		165.5	
	Total, 12 hours	− .06	− 3.8	+30	1,202.0	1,228.2	412.2	33.6
	Total, 24 hours				4,809.8		1,724.4	

TABLE 89.—*Amount of heat produced, and ratio of heat to carbon dioxid*—Continued.

Date.	Period.	(*a*) Rise (+) or fall (−) of body temperature.	(*b*) Gain (+) or loss (−) of body heat (0.83*a*× *w*).	(*c*) Assumed correction for bed and bedding.	(*d*) Heat eliminated, measured.	(*e*) Amount of heat produced, *b*+*c*+*d*.	(*f*) Carbon dioxid eliminated.	(*g*) Carbon dioxid per 100 calories of energy, 100*f*÷*e*.
	WORK EXPERIMENTS—Con.							
	Experiment No. 62, with A. L. L., carbohydrate diet—Con.							
1905.		°*C.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Grams.*
Apr. 18-19	7 a. m. to 10 a. m	+0.73	+45.7	−30	879.8	895.5	330.8	36.9
	10 a. m. to 1 p. m	− .89	−55.7		979.9	924.2	326.8	35.4
	Total, 6 hours	− .16	−10.0	−30	1,859.7	1,819.7	657.6	36.1
	1 p. m. to 4 p. m	+ .22	+13.8		944.3	958.1	335.9	35.1
	4 p. m. to 7 p. m				824.2	824.2	292.3	35.5
	Total, 6 hours	+ .22	+13.8		1,768.5	1,782.3	628.2	35.2
	Total, 12 hours	+ .06	+ 3.8	−30	3,628.2	3,602.0	1,285.8	35.7
	7 p. m. to 10 p. m	− .11	− 7.0		389.3	382.3	150.8	39.4
	10 p. m. to 1 a. m			+30	308.2		93.0	
	Total, 6 hours			+30	697.5		243.8	
	1 a. m. to 4 a. m				275.9		85.8	
	4 a. m. to 7 a. m				250.7		86.6	
	Total, 6 hours				526.6		172.4	
	Total, 12 hours	+ .05	+ 3.1	+30	1,224.1	1,257.2	416.2	33.1
	Total, 24 hours	+ .11	+ 6.9		4,852.3	4,859.2	1,702.0	35.0
	Experiment No. 63, with A. L. L., fat diet.							
Apr. 19-20	7 a. m. to 10 a. m	+ .73	+44.5	−30	940.1	954.6	329.3	34.5
	10 a. m. to 1 p. m	− .89	−54.2		946.4	892.2	301.3	33.8
	Total, 6 hours	− .16	− 9.7	−30	1,886.5	1,846.8	630.6	34.1
	1 p. m. to 4 p. m	+ .44	+26.8		960.4	987.2	322.1	32.6
	4 p. m. to 7 p. m	− .33	−20.1		842.7	822.6	256.5	31.2
	Total, 6 hours	+ .11	+ 6.7		1,803.1	1,809.8	578.6	32.0
	Total, 12 hours	− .05	− 3.0	−30	3,689.6	3,656.6	1,209.2	33.1
	7 p. m. to 10 p. m	+ .17	+10.4		407.3	417.7	122.2	29.3
	10 p. m. to 1 a. m			+30	315.0		104.0	
	Total, 6 hours			+30	722.3		226.2	
	1 a. m. to 4 a. m				275.2		83.7	
	4 a. m. to 7 a. m				259.6		82.6	
	Total, 6 hours				534.8		166.3	
	Total, 12 hours	+ .33	+20.1	+30	1,257.1	1,307.2	392.5	30.0
	Total, 24 hours	+ .28	+17.1		4,946.7	4,963.8	1,601.7	32.3
Apr. 20-21	7 a. m. to 10 a. m	+ .11	+ 6.7	−30	976.2	952.9	321.4	33.7
	10 a. m. to 1 p. m	− .33	−20.1		977.8	957.7	303.2	31.7
	Total, 6 hours	− .22	−13.4	−30	1,954.0	1,910.6	624.6	32.7
	1 p. m. to 4 p. m	+ .22	+13.4		862.6	876.0	301.2	34.4
	4 p. m. to 7 p. m	− .39	−23.8		810.0	786.2	263.3	33.5
	Total, 6 hours	− .17	−10.4		1,672.6	1,662.2	564.5	34.0
	Total, 12 hours	− .39	−23.8	−30	3,626.6	3,572.8	1,189.1	33.3

TABLE 89.—*Amount of heat produced, and ratio of heat to carbon dioxid*—Continued.

Date.	Period.	(*a*) Rise (+) or fall (−) of body temperature.	(*b*) Gain (+) or loss (−) of body heat, (0.83*a*× *w*).	(*c*) Assumed correction for bed and bedding.	(*d*) Heat eliminated, measured.	(*e*) Amount of heat produced, *b*+*c*+*d*.	(*f*) Carbon dioxid eliminated.	(*g*) Carbon dioxid per 100 calories of energy, 100*f*÷*e*.
	WORK EXPERIMENTS—Con.							
	Experiment No. 63, with A. L. L., fat diet—Con.							
1905.		°*C*.	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Grams.*	*Grams.*
Apr. 20-21	7 p. m. to 10 p. m	+0.17	+10.4		369.1	379.5	123.8	32.6
	10 p. m. to 1 a. m			+30	337.1		109.8	
	Total, 6 hours				706.2		233.6	
	1 a. m. to 4 a. m				292.2		70.2	
	4 a. m. to 7 a. m				275.8		88.0	
	Total, 6 hours				568.0		158.2	
	Total, 12 hours	+ .28	+17.1	+30	1,274.2	1,321.3	391.8	29.7
	Total, 24 hours	− .11	− 6.7		4,900.8	4,894.1	1,580.9	32.3
Apr. 21-22	7 a. m. to 10 a. m	+ .33	+20.1	−30	859.9	850.0	307.3	36.2
	10 a. m. to 1 p. m	− .50	−30.5		931.3	900.8	287.3	31.9
	Total, 6 hours	− .17	−10.4	−30	1,791.2	1,750.8	594.6	34.0
	1 p. m. to 4 p. m	+ .73	+44.5		917.3	961.8	321.4	33.4
	4 p. m. to 7 p. m	− .61	−37.1		842.7	805.6	262.8	32.6
	Total, 6 hours	+ .12	+ 7.3		1,760.0	1,767.3	584.2	33.1
	Total, 12 hours	− .05	− 3.0	−30	3,551.2	3,518.2	1,178.8	33.5
	7 p. m. to 10 p. m	− .06	− 3.7		364.8	361.1	124.8	34.6
	10 p. m. to 1 a. m				341.4		107.1	
	Total, 6 hours				706.2		231.9	
	1 a. m. to 4 a. m			+30	283.1		86.5	
	4 a. m. to 7 a. m				282.1		81.2	
	Total, 6 hours			+30	565.2		167.7	
	Total, 12 hours	+ .11	+ 6.7	+30	1,271.4	1,308.1	399.6	30.5
	Total, 24 hours	+ .06	+ 3.7		4,822.6	4,826.3	1,578.4	32.7
	SEVERE WORK EXPERIMENT.							
	Experiment No. 64, with A. L. L., fat diet.							
Apr. 22-23	7. a. m. to 10 a. m	+1.11	+66.5	−30	1,047.5	1,084.0	368.5	34.0
	10 a. m. to 1 p. m	−1.22	−73.1		993.4	920.3	304.7	33.1
	Total, 6 hours	− .11	− 6.6	−30	2,040.9	2,004.3	673.2	33.6
	1 p. m. to 4 p. m	+ .44	+26.4		1,139.0	1,165.4	392.1	33.6
	4 p. m. to 7 p. m				1,001.5		336.4	
	Total, 6 hours				2,140.5		728.5	
	Total, 12 hours			−30	4,181.4		1,401.7	
	7 p. m. to 10 p. m				1,121.6		384.0	
	10 p. m. to 1 a. m			+30	857.0		249.7	
	Total, 6 hours			+30	1,978.6		633.7	
	1 a. m. to 4 a. m				682.9		223.4	
	4 a. m. to 7 a. m				293.8		85.2	
	Total, 6 hours				976.7		208.6	
	Total, 12 hours			+30	2,955.3		942.3	
	Total, 24 hours	+ .11	+ 6.6		7,136.7	7,143.3	2,344.0	32.8

The figures in column *b* are obtained by multiplying together the specific heat of the body (0.83), the change in body temperature for the period given in column *a* and the body weight found in Table 122 of the Appendix. The values in column *c* are the estimated amount of heat absorbed or liberated by the bed and bedding in certain periods. Column *d* shows the amount of heat actually measured by the calorimeter. The algebraic sum of the values in columns *b*, *c*, and *d* gives what is here designated as the amount of heat produced in column *e*.

In some of the experiments the data for the rise or fall of body temperature are lacking; hence the actual heat production can not be computed, although this is more especially true for the shorter periods, the temperature changes for the total twenty-four hours having been quite generally ascertained. It is worthy of note that the temperature differences for these periods are considerable, showing that the assumption formerly made that the body temperature was the same each morning at 7 a. m. was erroneous. The figures in column *b* show that considerable allowance must be made for such changes. In the shorter periods, also, the variations in temperature cause very important differences between the measurement of heat eliminated and the quantity actually produced. For example, in experiment No. 58, on November 11, the body was 0.7° cooler in the period from 1 to 7 a. m. than in the preceding period, indicating that in that period the subject had eliminated 41.6 calories of heat more than it had actually produced.

Although the data in the table afford a valuable clue to the actual heat production as compared with the heat elimination, it should be remembered that the corrections given are hardly more than approximate, because, as previously stated, the data on which the allowance for heat absorbed and eliminated by the bed and bedding depends are as yet rather meager. Furthermore, the allowances for change in store of body heat due to gains or losses of material have not been made. It is of course incorrect to neglect changes in body weight, especially in experiments where there are large gains or losses of body material, including water; but the computations for the amount of heat involved in such gains or losses were not made, because in these experiments—the first of the series made with the improved form of apparatus—the technic for the weighing of the subject was by no means perfect, and it is not at all improbable that the computations of the amounts of elements and compounds gained or lost by the body were not as accurate as was desired. The total error in neglecting this factor is not very large as compared with the two grosser corrections for which allowance has been made in the table, but for extremely accurate work allowance should also be made for these changes. It is hoped that in subsequent experiments the record of body weight gained or lost and the computations for gains or losses of body material will render possible the correction for heat gained or lost by the body in this way.

CARBON DIOXID THERMAL QUOTIENT.

The computation of the ratios between the carbon dioxid eliminated and the heat produced in the oxidation of protein, fat, or carbohydrates in the body—designated as the carbon dioxid thermal quotient—was explained in a previous publication.[a] It was shown that about 39 grams of carbon dioxid are produced when 100 calories of heat are liberated by the oxidation of carbohydrates, about 29.5 grams per 100 calories by the oxidation of fat, and 34.5 grams per 100 calories in the case of protein.

The ratio between the carbon dioxid and heat eliminated in any experiment with man affords a clue as to the nature of the material burned. For example, if the subject was subsisting entirely on carbohydrates the carbon dioxid thermal quotient would approach 39, but the quotient could never actually be so large, because there is always some metabolism of protein accompanying carbohydrate metabolism which would lower the quotient toward the value 34.5. If the subject were subsisting in large part on fat, the carbon dioxid thermal quotient should approach 29.5, although here again the protein metabolism accompanying the fat metabolism and the practical impossibility of administering a diet without carbohydrates would tend to raise this somewhat.

For the computation of the carbon dioxid thermal quotient the heat production should be used rather than the heat elimination, as distinguished in the preceding section. In Table 89, in which the heat production was computed, the carbon dioxid thermal quotient is also recorded for different periods of the day in the several experiments. In a considerable number of cases, however, it was not possible to estimate the heat production, owing to lack of data for the necessary corrections. In these cases the quotients were computed from the measurement of heat eliminated. The average carbon dioxid thermal quotients for the different experiments and for the different periods are given in Table 90.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 170.

TABLE 90.—*Average carbon dioxid thermal quotients, metabolism experiments Nos. 56–58 and 60–67.*

Kind and subject of experiment.	Duration.	Six-hour periods.				Twelve-hour periods.		Twenty-four hour period.
		7 a. m. to 1 p. m.	1 p. m. to 7 p. m.	7 p. m. to 1 a. m.	1 a. m. to 7 a. m.	7 a. m. to 7 p. m.	7 p. m. to 7 a. m.	
Rest experiments.	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 58, with H. F., carbohydrate diet	3	31.4	37.1	34.4	35.0	34.0	34.6	34.3
No. 60, with B. F. D., carbohydrate diet	3	35.7	36.0	34.9	32.3	35.9	33.8	34.9
No. 65, with A. L. L., carbohydrate diet	1	34.2	33.4	[a]36.2	[a]31.8	[a]33.8	33.3	33.5
No. 66, with A. L. L., carbohydrate diet	1	[a]33.2	[a]34.8	[a]36.8	[a]30.9	35.7	32.7	34.3
No. 67, with A. L. L., carbohydrate	2	[a]33.9	[a]36.3	[a]38.1	[a]33.2	[a]35.1	[a]35.9	35.3
Average Nos. 65, 66, 67	4	[b]33.8	[a]35.2	[b]37.3	[a]32.3	[b]34.9	[b]34.5	34.6
Average Nos. 58, 60, 65, 66, 67	10	[b]33.7	[b]36.0	[b]35.7	[b]33.1	[b]34.9	[b]34.3	34.6
Work experiments.								
No. 56, with J. C. W., fat diet	3	[a]34.1	[a]33.9	[a]31.7	[a]30.9	[a]34.0	[a]31.4	33.4
No. 57, with J. C. W., carbohydrate diet	3	[a]37.2	[a]36.9	[a]37.3	[a]36.0	37.2	36.4	37.0
No. 61, with B. F. D., carbohydrate diet	1	[a]38.3	[a]32.7	[a]33.8	[a]30.6	[a]35.9	[a]32.4	[a]35.0
No. 62, with A. L. L., carbohydrate diet	3	[a]35.6	[a]36.0	[a]34.7	[a]33.5	[a]35.8	[a]34.2	[a]35.4
No. 63, with A. L. L., fat diet	3	33.6	33.0	[a]32.4	[a]29.5	33.3	30.1	32.4
Average Nos. 56, 57, 61, 62, 63	13	[b]35.4	[b]34.8	[a]34.0	[a]32.3	[b]35.1	[b]33.0	[b]34.6
Severe work experiment.								
No. 64, with A. L. L., fat diet	1	33.6	[a]34.0	[a]32.0	[a]31.6	[a]33.5	[a]31.9	32.8
Average Nos. 56, 57, 61, 62, 63, 64	14	[b]35.2	[b]34.7	[a]33.9	[a]32.3	[b]35.0	[b]32.9	[b]34.5
Average all experiments	24	[b]34.6	[b]35.3	[b]34.6	[b]32.6	[b]35.0	[b]33.5	[b]34.5

[a] Calculated from heat measured.
[b] Quotients calculated from heat measured included in average.

These quotients throw an interesting light upon the nature of the material burned in the body during the different periods. In the rest experiments the carbon dioxid thermal quotients for the twenty-four hours averaged not far from 35, thus indicating a material consumption of fat or protein as well as carbohydrates. During the work experiments the quotient is affected by two factors, the nature of the diet and the draft upon body material. In experiment No. 56, for example, the quotient is 33.4, the large proportion of the energy in the diet being derived from fat; whereas in experiment No. 57, in which the diet consisted mainly of carbohydrates, it is 37.0. The differences between carbohydrate and fat diets in experiments Nos. 62 and 63 are not as striking as in experiments Nos. 56 and 57, since during the carbohydrate diet of experiment No. 62, there were considerable drafts upon body fat. The quotient is, however, lower in the experiment with fat diet than in that with carbohydrate.

When the different periods of the day are taken into consideration, it is seen that, on the average, the quotient is lowest in rest experiments during the first and last 6-hour periods, and highest during the periods from 1 p. m. to 7 p. m., and from 7 p. m. to 1 a. m. During work experiments, the quotient is, on the average, the lowest during the period from 1 a. m. to 7 a. m., while on the other periods it is practically constant. One explanation of this low carbon dioxid thermal quotient during the early morning period may be that there is a replacement of the glycogen in the body by the oxidation of fat to glycogen. This would take place without elimination of carbon dioxid and the quotient would therefore be low.

The errors affecting the computation of the correct carbon dioxid thermal quotient are those pertaining to the estimation of the production of heat and carbon dioxid for short periods. As has been previously explained, the measurements of heat and carbon dioxid by the respiration calorimeter for 24-hour periods are very accurate, but the estimations for shorter periods involve assumptions that are only approximately accurate; yet to have the quotient of greatest value, it should be capable of accurate computation during short periods, since it is during these periods that fluctuations in the nature of the material burned are of the greatest significance. With the proposed changes in manipulation, some of which have been, indeed, embodied in our routine at the time of writing, the accuracy of the computation of this most important ratio will be considerably increased.

RESPIRATORY QUOTIENT.

Other relationships between the four prime factors determined by means of the respiration calorimeter are those between the carbon dioxid and the oxygen, between the oxygen and the heat, and those including the water elimination. The ratio between carbon dioxid eliminated and oxygen consumed, commonly called the respiratory quotient, plays such an important rôle in the estimation of energy by the indirect method in investigations with other forms of respiration apparatus that it demands special discussion here. In a previous report of investigations[a] in which the respiratory quotient was computed the oxygen consumption was estimated, but in the experiments here reported it was actually determined. The respiratory quotient has been computed for periods of three hours' duration, and also for twenty-four hours; indeed, in some of the experiments it could be ascertained for periods of six to ten days. The data are given in Table 114 of the Appendix.

With other forms of apparatus for determining this ratio, such as those of Zuntz, Loewy, Chauveau, and Tissot, the experiments are in general limited in duration to twenty to thirty minutes. For the study of certain problems in metabolism short experiments are perhaps of more value than those of much longer duration. It has been possible with the form of apparatus here described to make determinations of the respiratory quotient for periods as short as two hours, although the shortest here reported are three hours. The true significance of extremely short determinations, however, is open to question.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 168.

Assuming the complete oxidation of carbohydrates to carbon dioxid and water, a simple computation will show that the volume of oxygen required to oxidize 1 gram of the carbohydrate is exactly that of the carbon dioxid produced; hence the respiratory quotient, expressed as $\frac{CO_2}{O_2}$, will equal 1[a]. The material to be oxidized in carbohydrates consists of carbon and hydrogen. There is sufficient oxygen in the molecule to provide for the complete oxidation of the hydrogen; hence for the purposes of this discussion the oxidation of the carbohydrate may be considered as the oxidation of carbon, so that for every volume of oxygen consumed by the oxidation of pure carbon there is an equal volume of carbon dioxid produced.

In the combustion of fats, on the other hand, the amount of oxygen in the molecule is such as to correspond to the oxidation of only a portion of the hydrogen; consequently, when the fat molecule is oxidized, the oxygen absorbed is used to oxidize not only carbon to carbon dioxid, but also a not inconsiderable portion of the organic hydrogen to water. Since the respiratory gases are always saturated with water vapor at the temperature of the body, whether their source be in fat or carbohydrates, the water vapor may be ignored. A computation of the amount of oxygen required to oxidize 1 gram of fat, and the amount of carbon dioxid resulting from the oxidation, shows that the volume of oxygen absorbed is considerably larger than that of carbon dioxid eliminated, the respiratory quotient being for fats not far from 0.71.[a]

In the case of the oxidation of protein the computation of the respiratory quotient is somewhat complex, owing to the fact that a certain amount of carbon and hydrogen of the protein molecule is excreted unoxidized in the urine. From the best available data it is computed that the respiratory quotient for protein is not far from 0.81.[a]

It is therefore apparent that the respiratory quotient in an experiment with man will indicate with a certain degree of accuracy the nature of the material burned in the body. For example, if the subject were subsisting in large measure upon fat the respiratory quotient should approach 0.7, while if the diet were mainly carbohydrate in nature the respiratory quotient should approach 1.

Since both the respiratory and carbon dioxid thermal quotients serve as indices of the nature of the material burned, we should expect to find them agreeing so far as indicating the combustion of protein, fat, or carbohydrates is concerned. The respiratory quotients for the experiments here reported are recorded in Table 91, and for purposes of comparison the carbon dioxid thermal quotients are likewise given.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 170.

TABLE 91.—*Respiratory and carbon dioxid thermal quotients, metabolism experiments Nos. 56–58 and 60–67.*

Kind and subject of experiment.	Duration.	Carbon dioxid eliminated.		Oxygen consumed.		(*e*) Respiratory quotient ($b \div d$).	(*f*) Total heat produced.	(*g*) Carbon dioxid thermal quotient ($100\ a \div f$).
		(*a*) Weight.	(*b*) Volume.	(*c*) Weight.	(*d*) Volume.			
Rest experiments.	*Days.*	*Grams.*	*Liters.*	*Grams.*	*Liters.*		*Cals.*	*Gms.*
No. 58, with H. F., carbohydrate diet.	3	659.6	335.8	555.5	388.9	0.8635	1,926	34.3
No. 60, with B. F. D., carbohydrate diet	3	779.9	397.1	628.8	440.2	.9021	2,232	34.9
No. 65, with A. L. L., carbohydrate diet	1	815.0	414.9	729.2	510.4	.8130	2,430	33.5
No. 66, with A. L. L., carbohydrate diet	1	839.7	427.5	707.0	494.9	.8639	2,447	34.3
No. 67, with A. L. L., carbohydrate diet	2	951.8	484.6	794.5	556.1	.8713	2,695	35.3
Average Nos. 65, 66, 67	4	889.6	452.9	756.3	529.4	.8549	2,567	34.6
Average Nos. 58, 60, 65, 66, 67	10	787.7	401.0	657.8	460.5	.8716	2,274	34.6
Work experiments.								
No. 56, with J. C. W., fat diet	3	1,762.2	897.1	1,571.9	1,100.3	.8154	5,279	33.4
No. 57, with J. C. W., carbohydrate diet	3	2,011.5	1,024.1	1,576.1	1,103.3	.9282	5,435	37.0
No. 61, with B. F. D., carbohydrate diet	1	1,599.6	814.4	1,309.1	916.4	.8887	[1] 4,565	[2] 35.0
No. 62, with A. L. L., carbohydrate diet	3	1,707.4	869.3	1,386.2	970.4	.8958	[1] 4,821	[2] 35.4
No. 63, with A. L. L., fat diet	3	1,587.0	807.9	1,439.1	1,007.4	.8020	4,895	32.4
Average Nos. 56, 57, 61, 62, 63	13	1,754.2	893.0	1,479.2	1,035.4	.8625	[3] 5,066	[4] 34.6
Severe work experiment.								
No. 64, with A. L. L., fat diet	1	2,344.0	1,193.3	2,105.7	1,474.0	.8096	7,143	32.8
Average Nos. 56, 57, 61, 62, 63, 64.	14	1,796.3	914.5	1,523.9	1,066.7	.8588	[3] 5,214	[4] 34.5
Average of all experiments	24	1,376.1	700.5	1,163.0	814.1	.8641	[3] 3,989	[4] 34.5

[1] Total heat measured.
[2] Calculated from heat measured.
[3] Heat measured included in average where heat produced is not given.
[4] Quotients calculated from heat measured included in average.

During the rest experiments the respiratory quotient averaged not far from 0.87. With mixed diet with man it is commonly assumed that the respiratory quotient is near 0.9. The reason that the respiratory quotients in the rest experiments were lower than 0.9, in spite of the fact that the diet was sufficiently carbohydrate in nature to be designated a carbohydrate diet, is that in all these experiments there were considerable drafts upon body fat. With work experiments, on the other hand, the differences between fat and carbohydrate diets, especially in the case of experiments Nos. 66 and 67, are rather striking. In those experiments in which the fat diet was taken the respiratory quotient was much lower than in the experiments with the carbohydrate diet.

In general the carbon dioxid thermal quotient was closely parallel to the respiratory quotient, and consequently these two important ratios are in a certain sense confirmatory.

The interpretation of the respiratory quotients for short periods, especially in these earlier experiments, is not deemed advisable in this discussion, owing to the difficulty in obtaining accurate figures for both factors of the ratio for the periods from 10 p. m. to 1 a. m., and from 7 a. m. to 10 p. m. It may be stated that the respiratory quotients for short periods, which are given in detail in the Appendix, Table 114, are, in all probability, on the whole not far from correct. Subsequent experiments not yet ready for publication indicate that the respiratory quotients for even two-hour periods can be of great significance in interpreting the nature of material oxidized during the different periods of the day. Recognizing the possible sources of error, however, we do not deem it advisable to discuss these quotients in this place.

COMPARISON OF FORMER AND PRESENT METHODS OF COMPUTING GAIN OR LOSS OF BODY MATERIAL AND ENERGY.

The increase or decrease of body material in the metabolism experiments are computed from the gain or loss of elements as explained in detail on page 71. In former experiments, in which nothing was known regarding the oxygen consumption, it was assumed that the glycogen content of the body was the same at the end of each experimental day, and the gain or loss of elements was ascribed to the increase or decrease of body protein, fat, and water. In the present experiments, in which the amount of oxygen consumed was actually determined, the variations in the quantity of glycogen, as well as of the other compounds mentioned, are estimated. A comparison of the results obtained by the two methods of calculation is interesting in that it shows under what conditions the assumption of glycogen equilibrium is warranted. The former and the present methods of calculating gains and losses of body material are illustrated in the following tables in the case of both rest and work experiments. The results as formerly calculated are shown in Table 92.

Table 92.—*Gain or loss of body materials and energy as formerly calculated.*

Date.	(*a*) Nitrogen gained (+) or lost (—).	(*b*) Carbon gained (+) or lost (—).	(*c*) Hydrogen gained (+) or lost (—).	(*d*) Protein gained (+) or lost (—), *a*×6.0.	(*e*) Carbon in protein gained (+) or lost (—), *d*×0.528.	(*f*) Carbon in fat gained (+) or lost (—), *b*—*e*.	(*g*) Fat gained (+) or lost (—), *f*÷0.761.
1903.							
Rest experiment No. 58.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 10	—1.61	— 34.62	+24.31	— 9.66	— 5.10	— 29.52	— 38.79
Nov. 11	—2.22	— 41.32	—13.79	—13.32	— 7.03	— 34.29	— 45.06
Nov. 12	—2.79	— 52.36	—22.66	—16.74	— 8.84	— 43.52	— 57.19
Total, 3 days	—6.62	—128.30	—12.14	—39.72	—20.97	—107.33	—141.04
Average per day	—2.21	— 42.77	— 4.05	—13.24	— 6.99	— 35.78	— 47.01
Work experiment No. 64.							
1904.							
Apr. 22	+2.42	—194.06	+23.80	+14.52	+ 7.67	—201.73	—265.09

Date.	(*h*) Hydrogen in protein gained (+) or lost (—), *d*×0.07.	(*i*) Hydrogen in fat gained (+) or lost (—), *g*×0.119.	(*k*) Hydrogen in water gained (+) or lost (—), *c*—(*h*+*i*).	(*l*) Water gained (+) or lost (—), *k*÷0.1119.	(*m*) Energy of protein gained (+) or lost (—), *d*×5.65.	(*n*) Energy of fat gained (+) or lost (—), *g*×9.54.	(*o*) Total energy from material gained (+) or lost (—), *m*+*n*.
1903.							
Rest experiment No. 58.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
Nov. 10	—0.68	— 4.62	+29.61	+264.61	— 55	— 370	— 425
Nov. 11	— .93	— 5.36	— 7.50	— 67.02	— 75	— 430	— 505
Nov. 12	—1.17	— 6.81	—14.68	—131.19	— 95	— 546	— 641
Total, 3 days	—2.78	—16.79	+ 7.43	+ 66.40	—225	—1,346	—1,571
Average per day	— .93	— 5.60	+ 2.48	+ 22.13	— 75	— 449	— 524
1904.							
Work experiment No. 64.							
Apr. 22	+1.02	—31.55	+54.33	+485.52	+ 82	—2,529	—2,447

The scheme of calculation is simple. On the first day of the rest experiment, for example, there was, according to the analyses of food, excreta, and respiratory products, a loss of 1.61 grams of nitrogen and 34.62 grams of carbon, and a gain of 24.31 grams of hydrogen. The quantity of nitrogen lost corresponds to 9.66 grams protein, shown in column *d*. (In this case the nitrogen was multiplied by the factor 6 instead of 6.25 as formerly, because it has been found that in respect to body protein this factor probably more nearly represents the ratio between the nitrogen and the total protein.)

From data regarding the elementary analyses of animal protein, it is assumed that the body protein contains 52.8 per cent of carbon; hence the amount of protein, 9.66 grams, multiplied by 0.528 gives 5.10 grams of carbon as lost in the protein, shown in column *e*. The total loss of carbon was 34.62 grams, as shown in column *b*. The difference between this amount and that lost in protein gives, in column *f*, 29.52 grams as the quantity of carbon supposed to have been lost in fat, since it was assumed that there was no gain or loss of glycogen. According to the best data available, fat contains 76.1 per cent of carbon; therefore the quantity of carbon in column *f* is divided by 0.761, which gives the corresponding amount of fat, 38.79 grams, shown in column *g*.

In a similar manner the quantity of water lost in the body is ascertained. The quantity of protein lost contained 0.68 gram of hydrogen; that of fat lost 4.62 grams. The sum of these two deducted (algebraically) from the total quantity of hydrogen gained, 24.31 grams, is the quantity of hydrogen in water gained, which is equivalent to a gain of 264.61 grams of water.

The amount of energy in protein lost is calculated by the use of the factor 5.65, which corresponds to the heat of combustion of 1 gram of animal protein. The factor for fat is 9.54, the average heat of combustion of 1 gram of body fat. The values obtained from these calculations are shown in columns *m* and *n*, and their sum in column *o* represents the total energy of material gained or lost by the body.

The amounts of body materials gained or lost as computed by the later method are shown in Table 93.

TABLE 93.—*Gain or loss of body materials and energy as calculated in the experiments here reported.*

Date.	(*a*) Nitrogen gained (+) or lost (−).	(*b*) Carbon gained (+) or lost (−).	(*c*) Hydrogen gained (+) or lost (−).	(*d*) Oxygen gained (+) or lost (−).	(*e*) Protein gained (+) or lost (−), *a* × 6.0.	(*f*) Fat gained (+) or lost (−), $= +0.005C + 9.63H - 1.221O - 2.476N$.
1903.						
Rest experiment No. 58.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
November 10	−1.61	−34.62	+24.31	+236.43	−9.66	−49.24
November 11	−2.22	−41.32	−13.79	−56.55	−13.32	−59.33
November 12	−2.79	−52.36	−22.66	−135.25	−16.74	−47.86
Total, 3 days	−6.62	−128.30	−12.14	+44.63	−39.72	−156.43
Average per day	−2.21	−42.77	−4.05	−14.88	−13.24	−52.14
1904.						
Work experiment No. 64.						
April 22	+2.42	−194.06	+23.80	+290.74	+14.52	−131.26

TABLE 93.—*Gain or loss of body materials and energy as calculated in the experiments here reported*—Continued.

Date.	(*g*) Water gained (+) or lost (−), $=-1.248C$ $+7.920H$ $+0.128O$ $+0.460N$.	(*h*) Glycogen gained (+) or lost (−), $=+2.243C$ $-16.613H$ $+2.093O$ $-2.892N$.	(*i*) Energy of protein gained (+) or lost (−), $e\times5.65$.	(*k*) Energy of fat gained (+) or lost (−), $f\times9.54$.	(*l*) Energy of glycogen gained (+) or lost (−), $h\times4.19$.	(*m*) Total energy from materials gained (+) or lost (−) $k+l+m$.
1903.						
Rest experiment No. 58.	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
November 10	+265.26	+ 17.99	− 55	− 469	+ 75	− 449
November 11	− 65.91	+ 24.47	− 75	− 566	+103	− 538
November 12	−132.72	− 16.00	− 95	− 457	− 67	− 619
Total, 3 days	+ 66.63	+ 26.46	−225	−1,492	+111	−1,606
Average per day	+ 22.21	+ 8.82	− 75	− 497	+ 37	− 535
1904.						
Work experiment No. 64.						
April 22	+469.01	−229.15	+ 82	−1,252	−960	−2,130

The data in the first three columns of this table are identical with those in the same columns in Table 92. In column *d* the data regarding the gain or loss of oxygen by the body are given, which were not in the preceding table. The amount of protein gained or lost, column *e*, is computed in the same manner in both cases. The amounts of fat, water, and glycogen gained or lost, columns *f*, *g*, and *h*, are computed by means of the formulæ given in the column headings. These formulæ are explained in detail on page 72; it will suffice here to state that the quantities of the elements given in columns *a*, *b*, *c*, and *d* are substituted for their initials in the formulæ, and the indicated operations are performed. There are no data in Table 92 corresponding to those in column *h* of this table.

The energy of protein and of fat gained or lost is computed in the same way as in the preceding table; that from glycogen gained or lost is calculated by the factor 4.19, which corresponds to the heat of combustion of 1 gram of glycogen. The algebraic sum of the quantities in columns *i*, *k*, and *l* represents the total amount of energy gained or lost in body material, as given in column *m*.

For a ready comparison of the results obtained by the two methods of calculation the figures are summarized in Table 94.

TABLE 94.—*Comparison of gain or loss of body materials and energy as computed by both methods.*

Date.	(*a*) Protein gained (+) or lost (−), both methods.	Fat gained (+) or lost (−).		Water gained (+) or lost (−).		(*f*) Glycogen, gained (+) or lost (−), new method.
		(*b*) Old method.	(*c*) New method.	(*d*) Old method.	(*e*) New method.	
1903.						
Rest experiment No. 58.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
November 10	− 9.66	− 38.79	− 49.24	+264.61	+265.26	+ 17.99
November 11	−13.32	− 45.06	− 59.33	− 67.02	− 65.91	+ 24.47
November 12	−16.74	− 57.19	− 47.86	−131.19	−132.72	− 16.00
Total, 3 days	−39.72	−141.04	−156.43	+ 66.40	+ 66.63	+ 26.46
Average per day	−13.24	− 47.01	− 52.14	+ 22.13	+ 22.21	+ 8.82
1904.						
Work experiment No. 64.						
April 22	+14.52	−265.09	−131.26	+485.52	+469.01	−229.15

Date.	Energy of protein gained (+) or lost (−).		Energy of fat gained (+) or lost (−).		(*l*) Energy of glycogen gained (+) or lost (−), new method.	Total energy from material gained (+) or lost (−).	
	(*g*) Old method.	(*h*) New method.	(*i*) Old method.	(*k*) New method.		(*m*) Old method.	(*n*) New method.
1903.							
Rest experiment No. 58.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
November 10	− 55	− 55	− 370	− 469	+ 75	− 425	− 449
November 11	− 75	− 75	− 430	− 566	+103	− 505	− 538
November 12	− 95	− 95	− 546	− 457	− 67	− 641	− 619
Total, 3 days	−225	−225	−1,346	−1,492	+111	−1,571	−1,606
Average per day	− 75	− 75	− 449	− 497	+ 37	− 524	− 535
1904.							
Work experiment No. 64.							
April 22	+ 82	+ 82	−2,529	−1,252	−960	−2,447	−2,130

EXPERIMENT WITH SMALL DRAFTS UPON BODY MATERIAL.

Experiment No. 58, which is used here for illustration, was the first rest experiment in which the consumption of oxygen was measured. It has been shown, in the discussion of this experiment on preceding pages, that the diet was insufficient and the body consumed some of its own material to supply energy for its needs, but the draft upon body material was relatively slight because the amount of muscular activity in the subject was decidedly small.

The gain or loss of protein was computed, as already stated, the same way in each case. As formerly estimated there would be an increasing loss of fat, but as computed by the later method the loss was greatest on the second day and smallest on the third day. The average loss for the three days was about 5 grams per day larger according to the later method. There is a very close agreement in the results of the two methods of computing the gain or loss of water. According to the present method of interpreting the results, there appeared to be a small gain of glycogen on the first and second days and a loss on the third day, equivalent to a total gain of 26 grams for the three days, or an average of barely 9 grams per day, which approximates glycogen equilibrium for the body. The amount of energy in the body material lost, according to the former method, was 524 calories, whereas by the later method it was 535 calories.

In this particular experiment the assumption that the body was in glycogen equilibrium was fairly correct, and the above comparison indicates that there is no striking difference in the result in the methods of computing gain or loss of body material when such is the case. Indeed, the agreement is so close that it would seem doubtful whether, in an experiment in which glycogen equilibrium could be fairly well assured, the extra labor of determining the oxygen consumption would be advantageous; but it is rather difficult to insure conditions of glycogen equilibrium. It is perhaps remarkable that with such insufficient diet there was not a loss of glycogen. The diet in this experiment contained a very large proportion of carbohydrates, and it is possible that in such a case the amount of glycogen in the body would not be materially decreased under the conditions of the experiment.

EXPERIMENT WITH LARGE DRAFTS UPON BODY MATERIAL.

Although the glycogen content of the body may remain remarkably constant, even with a slight draft upon body material, when there is an excess of carbohydrates in the diet, as shown in the data just given, in certain experiments in which considerable amounts of body material are used to supply energy there may be a marked disturbance of the glycogen equilibrium. Body material will be drawn on when food is entirely withheld, as in fasting, or when the amount of food is considerably less than would be required to assure nitrogen and carbon equilibrium. This latter condition frequently exists in the so-called "work experiments." In fact, in planning the work experiments in these investigations it has seemed advisable to furnish food in quantities that would be appreciably less than those required by the body, with the idea that under such conditions the body may possibly be more economical in its utilization of the food. Such an experiment is No. 64, of one day's duration, in which the subject was engaged in severe muscular work, riding the bicycle ergometer for eleven hours out of the twenty-four. The results of both methods of computing the gain or loss of body material in this experiment are also given in Tables 92–94.

In this experiment there was a small gain of nitrogen and hydrogen and a large loss of carbon. According to the assumption that there was glycogen equilibrium and that all the carbon not concerned in protein should be ascribed to fat, there would be a loss of 265 grams of fat, but by the later method of computation, which divides the carbon between glycogen and fat, the loss of fat was but 131 grams and there was a loss of 229 grams of glycogen. This is far from glycogen equilibrium.

The amount of energy in the fat and glycogen lost was estimated to be 2,130 calories, whereas the quantity of fat that would be equivalent to the carbon lost if there had been glycogen equilibrium would involve 2,447 calories. Some idea regarding the relative accuracy of the two methods of estimating gain or loss of body material is afforded by comparison of the heat measured by the calorimeter during the experiment with that estimated to have been derived by the body from food and body material. Such a comparison is given in Table 95.

Table 95.—*Comparison of the income and outgo of energy as computed by both methods.*

Date.	Heat of combustion of food, feces, and urine as determined by bomb calorimeter.			(*d*) Available energy from food, *a*−(*b*+*c*).	Total energy from body material gained (+) or lost (−) as calculated.	
	(*a*) Food.	(*b*) Feces.	(*c*) Urine.		(*e*) Old method.	(*f*) New method.
1903.						
Rest experiment No. 58.	*Calories.*	*Calories.*	*Calories.*	*Calories*	*Calories.*	*Calories.*
Nov. 10	1,488	67	72	1,349	− 425	− 449
11	1,469	67	74	1,328	− 505	− 538
12	1,543	67	81	1,395	− 641	− 619
Total, 3 days	4,500	201	227	4,072	−1,571	−1,606
Average per day	1,500	67	76	1,357	− 524	− 535
1904.						
Work experiment No. 64.						
Apr. 22	5,393	210	128	5,055	−2,447	−2,130

Date.	Estimated energy from material oxidized in the body.		(*i*) Heat measured by the respiration calorimeter.	Heat measured greater (+) or less (−) than heat estimated.			
				Amount.		Proportion.	
	(*g*) Old method, *d*−*e*.	(*h*) New method, *d*−*f*.		(*k*) Old method, *i*−*g*.	(*l*) New method, *i*−*h*.	(*m*) Old method, *k*÷*i*.	(*n*) New method, *l*÷*i*.
1903.							
Rest experiment No. 58.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*	*Per cent.*
Nov. 10	1,774	1,798	1,819	+45	+21	+2.5	+1.2
11	1,833	1,866	1,846	+13	−20	+ .7	−1.1
12	2,036	2,014	2,047	+11	+33	+ .5	+1.6
Total, 3 days	5,643	5,678	5,712	+69	+34	+1.2	+ .6
Average per day	1,881	1,893	1,904	+23	+11	+1.2	+ .6
1904.							
Work experiment No. 64.							
Apr. 22	7,502	7,185	7,137	−365	−48	−5.1	− .7

The values in the columns *a*, *b*, and *c* are obtained from actual determinations of heats of combustion. The sum of the quantities in columns *b* and *c* deducted from that in column *a* gives the amount of energy derived from food, shown in column *d*. The quantity of energy from body material gained or lost, as calculated by the former method, is shown in column *e*, and by the present method in column *f*. The value in one or the other of these columns deducted algebraically from that in column *d* gives the amount of energy from material actually oxidized in the body, including both food and body material consumed, according to the method of computing the latter. In column *g* the values are those according to the former method of computing the gain or loss of body material, and those in column *h* according to the later method. In column *i* is shown the amount of heat eliminated by the body, as measured by the respiration calorimeter. In columns *k*, *l*, *m*, and *n* are shown the actual and percentage differences between the measured amount of heat and the amount estimated to have been derived by the body from the oxidation of food and body material.

In the results for experiment No. 58 the differences between the measured and the estimated energy are smaller on the second and third days of the experiment when the gain or loss of body material is computed by the former method, and larger on the other day than in the case of either of the three days when the gains or losses are computed by the later method. The average for the three days, however, shows a closer agreement when the computations are made by the later method. In the case of the work experiments, there is a much wider discrepancy between the heat measured by the calorimeter and that estimated to have been derived by the body from the oxidation of material when the amount of body material gained or lost is computed by the former method. In both cases the discrepancy between the measured and estimated energy, as shown in percentage in column *n*, is within the limits of accuracy of experimental methods; whereas that shown in column *m* is, in the case of the work experiment, far too wide.

In a large number of experiments, especially where the glycogen content of the body remains essentially unaltered, the estimation of the amounts of energy from material oxidized in the body are probably not far from correct when the gains and losses of body material are calculated as formerly; but, on the whole, the above comparison indicates that more accurate results are to be obtained when the later method of calculations is employed and the quantity of glycogen gained or lost is computed, as well as that of the other materials. For this purpose, of course, the direct determinations of oxygen are indispensable.

COMPARISON OF THE ESTIMATION OF THE AMOUNT OF OXYGEN CONSUMED WITH THE ACTUAL DETERMINATION.

In a previous publication[a] the amounts of oxygen consumed in the metabolism experiments there reported were estimated according to a method which was described in detail. In Table 96 are given the data for a comparison of the results of computations according to such method with the actual determinations of the amounts of oxygen consumed in a rest experiment, No. 58, and a work experiment, No. 64.

TABLE 96.—*Comparison of computed oxygen consumption with amounts actually determined in metabolism experiments Nos. 58 and 64.*

Date.		Total weight.	Nitrogen.	Carbon.	Hydrogen.	Ash.	Oxygen.
	Rest experiment No. 58.						
1903.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 10–11	Total income, excluding oxygen of respiration	1,285.00	6.58	149.82	129.23	10.00	989.37
	Total outgo	1,587.34	8.19	184.44	104.92	8.35	1,281.44
	Outgo greater or less than income	+302.34	+1.61	+ 34.62	−24.31	−1.65	+292.07
	Gains (+) or losses (−) of body materials:						
	Protein	− 9.66	−1.61	− 5.10	− .68	− .15	− 2.12
	Fat	− 38.79	....	− 29.52	− 4.62	....	− 4.65
	Water	+264.61	....	....	+29.61	....	+235.00
	Ash	+ 1.80	....	....	....	1.80	....
	Oxygen from air, estimated	520.30	....	....	....	....	520.30
	Oxygen from air, actually determined	528.50	....	....	....	....	528.50
Nov. 11–12	Total income, excluding oxygen of respiration	1,260.00	6.45	148.05	126.55	9.80	969.15
	Total outgo	1,921.36	8.67	189.37	140.34	8.30	1,574.68
	Outgo greater or less than income	+661.36	+2.22	+ 41.32	+13.79	−1.50	+605.53
	Gains (+) or losses (−) of body materials:						
	Protein	− 13.32	−2.22	− 7.03	− .93	− .20	− 2.94
	Fat	− 45.06	....	− 34.29	− 5.36	....	− 5.41
	Water	− 67.02	....	....	− 7.50	....	− 59.52
	Ash	+ 1.70	....	....	....	+1.70	....
	Oxygen from air, estimated	537.66	....	....	....	....	537.66
	Oxygen from air, actually determined	548.98	....	....	....	....	548.98
Nov. 12–13	Total income, excluding oxygen of respiration	1,218.00	6.95	154.75	121.41	10.60	924.29
	Total outgo	2,018.55	9.74	207.11	144.07	8.96	1,648.67
	Outgo greater or less than income	+800.55	+2.79	+ 52.36	+22.66	−1.64	+724.38
	Gains (+) or losses (−) of body materials:						
	Protein	− 16.74	−2.79	− 8.84	− 1.17	− .26	− 3.68
	Fat	− 57.19	....	− 43.52	− 6.81	....	− 6.86
	Water	−131.19	....	....	−14.68	....	−116.51
	Ash	+ 1.90	....	....	....	+1.90	....
	Oxygen from air, estimated	597.33	....	....	....	....	597.33
	Oxygen from air, actually determined	589.13	....	....	....	....	589.13

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 163.

TABLE 96.—*Comparison of computed oxygen consumption with amounts actually determined in metabolism experiments Nos. 58 and 64*—Continued.

Date.		Total weight.	Nitrogen.	Carbon.	Hydrogen.	Ash.	Oxygen.
	Work experiment No. 64.						
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 22	Total income, excluding oxygen of respiration	7,576.80	19.11	474.94	825.66	28.10	6,228.99
	Total outgo	9,552.68	16.69	669.00	801.86	21.23	8,043.90
	Outgo greater or less than income	+1,975.88	−2.42	+194.06	−23.80	−6.87	+1,814.91
	Gains (+) or losses (−) of body materials:						
	Protein	+ 14.52	+2.42	+ 7.67	+ 1.02	+ .22	+ 3.19
	Fat	− 265.09		−201.73	−31.55		− 31.81
	Water	+ 485.52			+54.33		+ 431.19
	Ash	+ 6.65				+6.65	
	Oxygen from air, estimated	2,217.48					2,217.48
	Oxygen from air, actually determined	2,105.65					2,105.65

The first column of figures gives the total weight of outgo and that of the income, excluding oxygen of respiration. On the first day the outgo was apparently 302.34 grams greater than the income. The amounts of nitrogen, carbon, hydrogen, and ash in the materials of income and outgo, as determined by analyses, and that of oxygen, as calculated by difference, are given in the remaining columns. During the experiment there were gains and losses of body material, which were assumed to have the composition shown in Table 15, and the quantities of oxygen in them were calculated accordingly. In experiment No. 58, for example, there was a loss from the body of 9.66 grams of protein, which contained 2.12 grams of oxygen; and of 38.79 grams of fat, which contained 4.65 grams of oxygen. There was a gain by the body of 264.61 grams of water, containing 235 grams of oxygen.

Deducting the 2.12 grams of oxygen in the protein lost and the 4.65 grams in the fat lost from the 235 grams in the water stored and adding the difference to the 292.07 grams of excess in outgo over income gives the estimated amount consumed from the air as 520.30 grams. This same value is likewise obtained from the figures for the total weight in the first column; or, in other words, the body gave off in products of respiration and retained in material stored 520.30 grams of oxygen over and above that which it secured from the food and drink and supplied in the protein and fat lost. Actual determinations by means of the respiration apparatus show that on this day the body consumed 528.50 grams, or 8.20 grams more than was estimated. A similar computation for the other two days of this experiment shows an agreement between the estimated amount of oxygen and that actually determined not far from that of the first day, the estimates being somewhat smaller on the first two days and slightly larger on the third day than the determinations. In fact, so far as this individual experiment is concerned, the estimations agree remarkably well with the actual determinations. This method of computation assumes that there is no material gain or loss of carbohydrates, which was the case in this particular experiment. Under such conditions the amount of oxygen consumed may be estimated by this method with reasonable accuracy.

In experiments in which there is a marked gain or loss of carbohydrates the method is inadequate, as is illustrated by the data for experiment No. 64, also given in Table 96, in which there was a marked draft upon body material and in the form of carbohydrates. Here the amounts involved are much larger, since the subject was at very severe muscular work. The table shows that the amount of oxygen estimated to have been absorbed from the air was 2,217.48 grams, whereas the actual determination by means of the respiration apparatus showed only 2,105.65 grams. While the error in experiment No. 58 was inappreciable for the average of the three days, amounting to but 0.8 per cent, the error in experiment No. 64 is relatively much greater—5.3 per cent. The large error in the estimation of the amount of oxygen consumed is, in a measure, comparable with the error in the estimation of the amounts of energy derived from material actually oxidized in the body, as given in Table 95.

FLUCTUATIONS IN BODY WEIGHT AS COMPARED WITH GAINS AND LOSSES OF BODY MATERIAL.

Theoretically, the gains or losses of body material, as computed from data obtained by means of the respiration calorimeter, should give a true measure of the actual gains or losses in body weight. The net gain or loss thus computed should compare with that derived from the data obtained by means of the weighing apparatus mentioned on page 194. Such comparisons are made in Table 97 for those experiments in which the improved weighing apparatus was used.

TABLE 97.—*Comparison of gains and losses of body material with gains and losses of body weight in metabolism experiments Nos. 62–68.*

Experiment No.		Estimated gains and losses of body material.						Actual body weight by balance.	Gain (+) or loss (−) by balance.
		Protein.	Fat.	Carbohydrate.	Water.	Ash.	Total.		
62	Carbohydrate diet, work:								
	Preliminary weighing	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.* 75,085.6	*Grams.* ....
	First day	− 0.12	− 26.65	− 46.37	+ 137.17	+ 3.62	+ 67.65	75,443.4	+357.8
	Second day	− 2.82	− 13.31	− 82.39	+ 600.29	+ 3.26	+ 505.03	75,413.6	− 29.8
	Third day	−12.72	− 34.65	− 20.92	− 241.08	+ 1.10	− 308.27	75,269.4	−144.2
	Average per day	− 5.22	− 24.87	− 49.89	+ 165.46	+ 2.66	+ 88.14	....	+ 61.3
63	Fat diet, work:								
	First day	+ 8.70	− 13.35	− 68.28	−1,301.75	− 3.47	−1,378.15	74,319.0	−950.4
	Second day	−19.62	− 63.38	+ 33.57	− 629.37	−10.20	− 689.00	73,479.6	−839.4
	Third day	−25.02	− 63.35	+ 27.05	− 787.93	− 6.98	− 856.23	72,528.1	−951.5
	Average per day	−11.98	− 46.69	− 2.55	− 906.35	− 6.88	− 974.45	....	−913.8
64	Fat diet, work	+14.52	−131.26	−229.15	+ 469.01	+ 6.87	+ 129.99	72,158.8	−369.3
65	Carbohydrate diet, rest	−56.82	−128.39	+264.05	+ 383.93	+ 5.25	+ 468.02	72,519.8	+361.0
66	.....do	−54.30	− 75.43	+ 90.18	+ 396.03	+ 1.45	+ 357.93	72,979.8	+460.0
67	.....do	−46.62	− 80.06	+ 49.13	− 8.72	− .61	− 86.88	73,024.8	+ 45.0
	.....do	−40.56	− 67.91	+ 6.41	− 473.11	− 4.69	− 579.86	72,406.8	−618.0

The total estimated amount of body material gained or lost is the algebraic sum of the gains or losses of protein, fat, carbohydrate, water, and ash. The actual body weight as obtained at 7 a. m. by the balance is recorded in the next to the last column, and the fluctuations in body weight are given in the last column. The values in this last column should, theoretically at least, agree with the total estimated gains or losses of body material. An inspection of the figures in these two columns shows many marked discrepancies, especially noticeable in the first two days of experiment No. 62 and in experiment No. 64.

On the first day of experiment No. 62 the prescribed routine was not followed closely. There was, according to the experimental data, a loss of 0.12 gram of protein, 26.65 grams of fat, and 46.37 grams of carbohydrates, with a gain of 137.17 grams of water and 3.62 grams of ash, making a total gain of 67.65 grams, as compared with a gain of 357.8 grams as indicated by the balance. Similarly, on the second day there was a large gain of water, which compensated for the losses in fat and carbohydrates and resulted in a total gain for the day rather than a loss as indicated by the balance. On the third day there was a decided loss, even greater than that recorded by the balance. The results, as determined by the balance and by the computations of gains or losses of materials, agree more closely in experiment No. 63. In the average for the three days in each experiment the gain or loss of weight as estimated agrees with that ascertained by the balance quite as well as was to be expected in the first attempts to use the apparatus. The errors influencing the comparison mentioned below affect the first one (No. 62) more especially, and are of less importance in the second. The percentage discrepancy in the average result is much larger in the former than in the latter. The results in experiments Nos. 64–67 compare, in general, fairly well, though not as closely as desired.

Further experience in the use of the apparatus has shown the necessity of considering certain factors that were not taken sufficiently into account in these experiments, thus indicating possible causes for the discrepancies noted. Especial care is needed in collecting the urine at the proper time and in allowing for the weight of the feces; and the clothing worn by the subject when weighed must be carefully noted, though in the above experiments probably little of the discrepancy was due to error in this respect, because the observers paid particular attention to this point. Furthermore, proper allowance must be made for the drip water, and for variations in the amount of water condensed on the heat-absorbing system. In view of the improvement in technic that has been made in subsequent use of the apparatus the discrepancies noted above are not surprisingly large. In later experiments the agreement between the gain or loss in body weight as ascertained from the computed gain or loss of body material and as determined by use of the balance is very satisfactory.

INFLUENCE OF CHARACTER OF DIET ON BODY WEIGHT.

It has long been recognized that diets markedly one-sided with regard to their content of fat or carbohydrates have appreciable influence upon body weight. This observation has been frequently made in this laboratory, as well as by other investigators. In earlier experiments not much stress was placed upon these gains or losses, since it was considered that the methods of determining changes in body weight were not sufficiently accurate to warrant any definite conclusions. With the introduction of the new balance much more accurate observations were possible, and consequently definite data from which conclusions can legitimately be drawn are now available. Of the experiments reported in this bulletin, the first two in which the new balance was used, No. 62 with a carbohydrate diet and No. 63 with a fat diet, afford excellent opportunity for studying the relative effect of such diets upon the body weight, although, as has been pointed out in the preceding section, the data regarding body weight are probably more open to error in the first than the second experiment. The data for the comparison of the two experiments are given in Table 98.

Table 98.—*Comparison of total weight of food and drink ingested, and of gains and losses of body weights, in metabolism experiments Nos. 62 and 63 with A. L. L., on carbohydrate and fat diets.*

Date.	Character of diet.	Food and drink.			Body weight at 7 a. m.	Gains(+) or losses(−) of body weight.
		Solid matter.	Water.	Total.		
1904.						
Experiment No. 62.		*Grams.*	*Grams.*	*Grams.*	*Kgms.*	*Grams.*
Apr. 16					75,085.6	
16–17	Carbohydrate	969.6	3,577.3	4,546.9	75,443.4	+357.8
17–18	do	965.9	3,553.2	4,519.1	75,413.6	− 29.8
18–19	do	965.9	3,491.1	4,457.0	75,269.4	−144.2
Average per day		967.2	3,540.5	4,507.7		+ 61.3
Experiment No. 63.						
Apr. 19–20	Fat	750.5	3,108.1	3,858.6	74,319.0	−950.4
20–21	do	745.4	4,150.3	4,895.7	73,479.6	−839.4
21–22	do	746.9	4,151.9	4,898.8	72,528.1	−951.5
Average per day		747.6	3,803.4	4,551.0		−913.8

The carbohydrate diet furnished about 967 grams of solid matter and sufficient water, including both that in the food and that drunk, to make a total weight of about 4,500 grams per day. On this diet the body weight, as determined by the balance, increased 61.3 grams per day. The computation for the gains or losses of body material, Table 97, showed a slightly greater average gain per day. The fat diet contained about 750 grams of solid matter and sufficient water to make up 3,859 grams on the first day and practically 4,900 grams on the other two days, so that the total weight of food and drink was slightly larger in the second experiment, averaging 4,551 grams per day. In spite of this fact, on the fat diet there was a very marked tendency toward a loss in body weight, and specifically, as may be seen by reference to the computations of gains or losses of body material in Table 97, toward a loss of water. The quantity of energy furnished by both diets was practically uniform, and the amount of external muscular work performed was identical. The amount of heat eliminated by the body was, on the average, 69 calories larger in the experiment with the fat diet. The gains or losses of body material were such that, during the experiment with the carbohydrate diet, there was an average loss of 5.22 grams of protein, 24.87 grams of fat, and 49.89 grams of carbohydrates, with a gain of 165.46 grams of water and 2.66 grams of ash, whereas in the experiment with the fat diet there was an average loss of 11.98 grams of protein, 46.69 grams of fat, 2.55 grams of carbohydrates, 906.35 grams of water, and 6.88 of ash, thus showing that the transition from the carbohydrate to the fat diet resulted in a marked loss of water by the body. No observations on man of which we are aware give information as to how long this loss of water will take place, and experiments of this nature are greatly to be desired.

The recent observations by A. Gouin and P. Andouard[a] show that in animal tissues the water content is much greater after feeding with sugar than before.

Perhaps the most striking conclusion from this comparison is that the body weight is of little value in showing the true gains or losses of protein, fat, or carbohydrate by the body. In these experiments with diets furnishing energy nearly sufficient to meet the demands of the body in both cases there was a slight gain in one and a marked loss in body weight in the other, amounting to 2.82 kilograms. This loss was, as the experimental data show, mainly water.

AMOUNTS OF ENERGY SUPPLIED IN DIFFERENT NUTRIENTS. BODILY ACTIVITY.

The rations in these experiments varied considerably from the ordinary mixed diet. They were made as palatable as possible under the circumstances and to the liking of the subject, but certain kinds of food were necessarily excluded, owing to difficulties in sampling, analyzing, etc. Only a few simple foods were included of such a nature that the quantities of the different nutrients and of energy in the diet could be maintained fairly uniform from day to day. The amounts of the different foods supplied to the subjects varied with the nature of the several experiments, consequently the total potential energy of the different nutrients was not the same in all the experiments. In some cases large amounts of energy were derived from fats and in others from carbohydrates, but in no case was the quantity of potential energy in the protein of the diet larger than normal. The average total daily income of energy to the body in each of the eleven experiments is shown in detail in the following table:

Table 99.—*Itemized income and outgo of energy per day in metabolism experiments Nos. 56–58 and 60–67.*

Experiment number, subject, and character of diet.	Income of energy.											
	From protein.				From fat.				From carbohydrates.			
	Of food.	Of body.	Total.	Proportion of total income.	Of food.	Of body.	Total.	Proportion of total income.	Of food.	Of body.	Total.	Proportion of total income.
	Cals.	*Cals.*	*Cals.*	*Per ct*	*Cals.*	*Cals.*	*Cals.*	*Per ct*	*Cals.*	*Cals.*	*Cals.*	*Per ct*
56, J. C. W.; fat	642	− 20	622	10.9	3,207	+ 67	3,274	57.2	1,849	− 24	1,825	31.9
57, J. C. W.; carbohydrate	613	+ 6	619	10.6	792	+ 205	997	17.2	4,082	+ 112	4,194	72.2
58, H. F.; carbohydrate	227	+ 75	302	14.9	248	+ 497	745	36.8	1,016	− 37	979	48.3
60, B. F. D.; carbohydrate	577	+ 21	598	24.7	478	− 36	442	18.2	1,468	− 86	1,382	57.1
61, B. F. D.; carbohydrate	571	+ 80	651	13.7	1,506	− 94	1,412	29.6	1,539	+1,162	2,701	56.7
62, A. L. L.; carbohydrate	580	+ 30	610	12.0	1,066	+ 237	1,303	25.6	2,968	+ 209	3,177	62.4
63, A. L. L.; fat	585	+ 68	653	12.5	2,778	+ 445	3,223	61.9	1,319	+ 11	1,330	25.6
64, A. L. L.; fat	663	− 82	581	7.7	3,378	+1,252	4,630	61.5	1,361	+ 960	2,321	30.8
65, A. L. L.; carbohydrate	545	+321	866	30.6	281	+1,225	1,506	53.1	1,568	−1,106	462	16.3
66, A. L. L.; carbohydrate	499	+307	806	29.4	278	+ 720	998	36.5	1,312	− 378	934	34.1
67, A. L. L.; carbohydrate	389	+246	635	21.2	273	+ 706	979	32.7	1,498	− 117	1,381	46.1

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[a] Compt. Rend. Soc. Biol. [Paris], 58 (1905), 17, p. 813.

TABLE 99.—*Itemized income and outgo of energy per day in metabolism experiments Nos. 56–58 and 60–67*—Continued.

Experiment number, subject, and character of diet.	Total income of energy.						Outgo of energy.				
	Heat of combustion of food.		From body.		Estimated energy of body material plus energy of food as—						
	Calculated.	Determined.	Amount.	Proportion of total income.	Calculated.	Determined.	In feces.	In urine.	As heat.	As external muscular work.	Grand total.
	Cals.	*Cals.*	*Cals.*	*Per ct.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*	*Cals.*
56, J. C. W.; fat	5,698	5,565	+ 23	0.4	5,721	5,588	309	138	4,715	569	5,731
57, J. C. W.; carbohydrate	5,487	5,532	+ 323	5.6	5,810	5,855	268	128	4,833	602	5,831
58, H. F.; carbohydrate	1,491	1,500	+ 535	26.4	2,026	2,035	67	76	1,904	......	2,047
60, B. F. D.; carbohydrate	2,523	2,509	− 101	− 4.2	2,422	2,408	132	129	2,228	......	2,489
61, B. F. D.; carbohydrate	3,616	3,614	+1,148	24.1	4,764	4,762	161	138	4,146	419	4,864
62, A. L. L.; carbohydrate	4,614	4,636	+ 476	9.4	5,090	5,112	229	131	4,362	459	5,181
63, A. L. L.; fat	4,682	4,753	+ 524	10.1	5,206	5,277	210	136	4,431	459	5,236
64, A. L. L.; fat	5,402	5,393	+2,130	28.3	7,532	7,523	210	128	6,180	957	7,475
65, A. L, L.; carbohydrate	2,394	2,369	+ 440	15.5	2,834	2,809	92	176	2,453	......	2,721
66, A. L. L.; carbohydrate	2,089	2,062	+ 649	23.7	2,738	2,711	92	157	2,471	......	2,720
67, A. L. L.; carbohydrate	2,160	2,115	+ 835	27.9	2,995	2,950	92	130	2,689	......	2,911

In the above summary the total income of energy to the body is considered as the potential energy of the food plus that of body material lost or less that of body material stored. The estimation of the potential energy of the body material stored or lost has already been explained (p. 75). The amounts of energy as thus computed on the preceding pages are here summarized.

The total potential energy of the food is its heat of combustion as directly determined. A column in the table above contains the data regarding the total determined heat of combustion of the daily food in each experiment. In addition to this, for use in discussion of several topics on subsequent pages, the total potential energy of the protein, the fat, and the carbohydrate of the diet in each experiment is also given. It is manifestly impracticable to make actual determinations of these values. They are computed from the detailed data of the various experiments regarding the quantity of each nutrient in the different kinds of food in the ration and the best available data regarding the heat of combustion of the several nutrients in different kinds or classes of food materials.[a]

The sum of the quantities of potential energy of the protein, fat, and carbohydrate of the diet is the estimated total energy of the diet.

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[a] Connecticut (Storrs) Sta. Rpt., 1899, p. 104.

In a large majority of the cases the heat of combustion thus estimated agrees very satisfactorily with that actually determined. The estimation of the potential energy of the several nutrients may therefore be considered sufficiently accurate for the purposes for which the figures are used on later pages. These results are especially interesting in showing the large proportion of energy of the fat in the so-called fat diets and of the carbohydrates in the carbohydrate diets and the difficulty of eliminating entirely either of these nutrients from a diet in which the other preponderates.

The total outgo of energy consists of the heat of combustion of the unoxidized material of feces and of urine, the energy eliminated from the body directly as heat, and as external muscular work.

As a result of the large number of experiments which have been made with the respiration calorimeter in the past decade, it is more and more clear that the amounts of matter and energy katabolized in the body are decided almost wholly by its activity. Muscular work may be said to be the factor determining metabolism.

Muscular work consists of the internal physiological work, such as that of circulation, respiration, peristalsis, etc., and of voluntary muscular action. The latter may be divided into major movements and minor movements. The major movements consist, in experiments of the type here reported, of rising, dressing, weighing of self and bedding, changing position from sitting to standing or reclining, or walking to and fro within the limits of the chamber, the muscular work of eating and drinking, and the manipulations incidental to care of food and excreta and adjusting the furniture; and, obviously, in experiments on muscular work, the movements incidental to riding the bicycle ergometer are of very great importance. The minor movements consist in turning over in bed, changing the position while sitting, moving the hands, arms, and legs without other change of position, and the activities incidental to reading and to writing with a pen. The position of the telephone inside the chamber was such that the subject could use it without rising from the chair, and, consequently, telephoning also may be classed as a minor movement. By far the larger number of movements in a rest experiment, that is, one without prescribed muscular work, are of this class.

While it is perfectly clear that muscular work on the bicycle ergometer involves a very large transformation of matter and energy, and the other major movements likewise but to a lesser degree, it is also true that the minor movements involve much greater transformations than is commonly supposed, and such movements must be considered when interpreting the results of experiments which are supposed to be otherwise comparable. It is difficult for one who has not taken some notice of them to imagine the large number of minor muscular movements made by a man in the course of twenty-four hours. Even when the subject sits reading or lies sleeping the number of small movements is large.

This is well illustrated by the records given on page 86 in connection with the data of experiment No. 58. Although this subject had trained himself to control his activities and was asked to restrict them, his bodily activity was appreciable each day; and of particular interest is the fact that the number and kind of actions differed somewhat from day to day, so that if all other conditions had been equal the heat output would have varied day by day from this cause.

The number of movements by this subject is probably a minimum for a man under the conditions obtaining in these experiments. With ordinary subjects it is very greatly increased. Our experience in these investigations agrees fully with that of other investigators who find difficulty in securing complete body repose during periods of any considerable length of time. In fact, this forms the basis of a very serious criticism against experiments of short periods, especially those less than an hour. In our judgment it is in many cases possible to obtain comparable experiments only by making the experimental period cover several hours in which variations in muscular activity will more or less equalize. To attempt to compare periods of fifteen to thirty minutes, in which there may be marked variations in muscular activity in spite of the muscular control of the subject, is futile, since, as experimental evidence accumulates, it is becoming more and more clear that experiments in which the bodily activity is not uniform are not comparable. To secure such uniformity is, with the majority of subjects, a very difficult problem. In order to eliminate as far as possible the discrepancies arising from fluctuations in muscular activity, we must therefore rely on a large number of experiments with different individuals in which the average fluctuations from bodily activity will be the same.

MUSCULAR WORK ON THE ERGOMETER.

The relation of muscular work to metabolism is not specially discussed in the present bulletin, but a comparison of the relative values of fats and carbohydrates as sources of energy for muscular work is given beyond. The methods of measuring muscular work in the work experiments here reported were very much more satisfactory than in those previously reported. The error in the results of such measurements in earlier experiments is considerable, but in these it is probably negligible. The bicycle ergometer (p. 48) is so constructed and calibrated that the amount of work done is directly proportional to the number of revolutions of the pedals, provided that the electric current passing through the magnet is uniform. Care was taken in all the experiments here recorded to have the current exactly the same on all days. The record of the work done on the ergometer in all the work experiments reported in this bulletin is given in Table 120 in the Appendix. In the first column is recorded the date of the experiment; in the second, the actual time during which the work was done; in the third, the length of the period in hours and minutes; in the fourth, the number of revolutions of the pedals, and in the fifth, the heat equivalent of the total work.

The actual number of revolutions of the pedals, and consequently the heat equivalent of the work done, varied slightly on the different days. In the three days of experiment No. 56 the number of revolutions ranged from 23,092 to 25,836, and the heat equivalent of the total work done from 538 to 602 calories. The heat equivalent of the total work done during the three days of experiment No. 56 was 1,708 calories. In experiment No. 57 the total number of revolutions varied from 24,156 to 28,212 per day, with the corresponding variation in the heat equivalent of total work, i. e., from 563 to 657 calories. The total heat equivalent of the work done for three days in experiment No. 57 was about 100 calories greater than in experiment No. 56. In experiment No. 61 the work done was considerably less than in any day of experiments Nos. 56 and 57, as the subject was by no means so used to muscular work. On each of the six days of experiments Nos. 62 and 63 the total number of revolutions per day was 19,700, and the heat equivalent of the work done was 459 calories. On the one day of experiment No. 64, when the excessive muscular work was performed, the total amount of work done was more than twice that per day in Nos. 62 and 63, the number of revolutions being 41,000, and the heat equivalent of external muscular work, 957 calories.

FATS VERSUS CARBOHYDRATES AS PROTECTORS OF BODY MATERIAL.

The growing custom of estimating the energy from carbohydrates and fats as equivalent both as sources of muscular work and for the protection of body material is based in large measure upon actual experiment. One criticism of the deductions from the results of the experiments thus far reported, however, is that it is extremely difficult to secure diets with like quantities of energy during one period in fat and in the other period in carbohydrates, in which the digestibility of the food shall be alike in both experiments. In the series of experiments here reported, there are two sets of experiments, Nos. 56 and 57, and Nos. 62 and 63, that permit of the comparison of fats and carbohydrates as protectors of body material. These are summarized in Table 100.

TABLE 100.—*Fats versus carbohydrates as protectors of body material.*

Experiment number, character, and subject.	Kind of diet.	Duration.	Amount per day.				
			Available energy of food.	Energy of external muscular work.	Gain or loss of body material.		
					Protein.	Fat.	Carbohydrates.
		Days.	*Calories.*	*Calories.*	*Grams.*	*Grams.*	*Grams.*
56, work, J. C. W	Fat	3	5,118	569	+ 3.52	− 7.03	+ 5.83
57, work, J. C. W	Carbohydrates	3	5,136	602	− 1.12	−21.48	−26.76
62, work, A. L. L	do	3	4,276	459	− 5.22	−24.87	−49.89
63, work, A. L. L	Fat	3	4,407	459	−11.98	−46.69	− 2.55

In experiments Nos. 56 and 57 the amount of available energy was practically the same in both diets. Unfortunately, the amount of external muscular work was somewhat greater on the carbohydrate than on the fat diet, and it is furthermore to be regretted that the experiments were separated by several days, during which time no observations on the gain or loss of body material were made. The loss of body material was greater in experiment No. 57 than in experiment No. 56, but this may be due to the fact that the external muscular work was greater, and a comparison is still possible, if due allowance be made for the fact that the extra 33 calories of external muscular work in experiment No. 57 would increase the drafts upon body material. It is nevertheless difficult to obtain from the data in these two experiments any definite conclusions regarding the relative efficiency of the fats and the carbohydrates as protectors of body material. In experiments Nos. 62 and 63, on the other hand, the external muscular work was purposely made the same in both, but unfortunately the amount of available energy was considerably less in the carbohydrate than in the fat diet, owing to a change in the diet that was necessary to make it palatable to the subject. With both diets, there was a draft upon the body material, but even with the excess of available energy in the food, the draft upon body protein and body fat was greater with the fat diet than with the carbohydrate diet. On the other hand, the draft upon body carbohydrate was much less. The difference in the amounts of available energy of the food makes the comparison somewhat difficult, but it would appear from the results of these two experiments that the fats were somewhat less efficient than the carbohydrates as protectors of body material.

Regarding the gain or loss of body protein, it is important to note that fluctuations in diet produce marked fluctuations in the elimination of nitrogen in the urine. These fluctuations may be considered as concurrent with the disintegration of proteid material, though it is yet to be settled by more extensive experimenting whether this is absolutely the case or not. The assumption that there is neither retention nor sweeping out of nitrogen from the system with the alteration in diet other than that caused by the corresponding disintegration or storage of body material is, in our judgment, not sufficiently well founded to form a basis for the statement that fat does not protect body protein to as great an extent as carbohydrates. The discussion of the protection of body fat or carbohydrates by the carbohydrates or fat in the diet may be perhaps more intelligently considered when the total energy involved in metabolism is taken into account.

PROTEIN AS THE SOURCE OF MUSCULAR WORK.

A comparison of the heat equivalent of the external muscular work with the energy of the protein metabolized in the work experiments is interesting in view of the opinion held by Pflüger and Argutinsky[a] that the metabolism of protein is the source of muscular work.

As previously stated, the measurement of external muscular work in the respiration calorimeter experiments in which the present form of ergometer is used is quite accurate. The heat equivalent of the external muscular work, the energy of the protein oxidized and the total amount of energy transformed, are summarized in Table 101.

TABLE 101.—*Comparison between energy of total protein oxidized and energy of external muscular work—Average per day.*

Experiment.	Duration.	Heat equivalent of external muscular work.	Energy of protein oxidized.	Total energy transformed.
Carbohydrate diet.	*Days.*	*Calories.*	*Calories.*	*Calories.*
No. 57, subject J. C. W	3	602	421	5,435
No. 61, subject B. F. D	1	419	474	4,565
No. 62, subject A. L. L	3	459	425	4,821
Average Nos. 57 and 62	6	531	423	5,128
Average above experiments	7	515	430	5,048
Fat diet.				
No. 56, subject J. C. W	3	569	449	5,284
No. 63, subject A. L. L	3	459	490	4,890
No. 64, subject A. L. L	1	957	431	7,137
Average Nos. 56 and 63	6	514	470	5,087
Average above experiments	7	577	464	5,380
Average Nos. 57, 62, 56, and 63	12	523	447	5,108
Average above 6 experiments, fat and carbohydrate diets	14	546	447	5,214

In four of the six experiments the energy of protein oxidized was considerably less than that of the external muscular work performed. This of itself may be advanced as an argument against the theory that external muscular work is chiefly derived from oxidation of protein. In a previous report [a] a similar comparison was made, and there was included in the experiments one in which an unusual amount of muscular work was performed, equivalent to 1,482 calories in twenty-four hours, during which period the energy of the protein oxidized amounted to but 478 calories. In the present series of experiments No. 64 is of a similar nature. In this case the heat equivalent of external muscular work was 957 calories, while the energy of the protein oxidized was but 431 calories.

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[a] Arch. Physiol. [Pflüger], 46 (1889–90), p. 552, and 50 (1891), p. 98.

In the earlier report it was assumed that all the nitrogen resulting from the disintegration of protein on the days of severe work was excreted on that day, though it was pointed out that there may have been a lag in elimination of nitrogen from the katabolized body protein. As a matter of fact the urine was collected for two days following this experiment, and a very marked increase [b] in the elimination of nitrogen was observed; but unfortunately during these two days an exact record of the food eaten was not kept, consequently there was no evidence that the increased nitrogen elimination might not have been a result of an increased ingestion of protein rather than an increased elimination due to extra katabolism of body protein on the preceding day of severe muscular work.

In experiment No. 64, here reported, the heat equivalent of external muscular work was over twice that of the energy of the protein oxidized. Here also there was a very marked increase in the elimination of nitrogen on the days following the experiment, as shown in Table 106 of the Appendix. But with all due allowance for any delay in the excretion of nitrogen resulting from the katabolism of protein induced by severe muscular work, the total probable disintegration is still far from sufficient to supply all the energy for external muscular work. Further experiments designed more specifically to study the relations between the protein oxidized and the heat equivalent of muscular work are planned, and it is hoped that more data on this problem will soon be accumulated, but at present these experiments do not warrant the conclusion that protein is to be regarded as the sole or the principal source of muscular energy.

RELATIVE EFFICIENCY OF FATS AND CARBOHYDATES IN RATIONS FOR MUSCULAR WORK.

Experiments Nos. 62 and 63 furnish data for comparing the relative efficiency of fats and carbohydrates as sources of energy for muscular work. The amount of muscular work performed was exactly the same in both experiments, and in both cases the amount of energy was insufficient to meet the demands of the body. One ration contained a considerable proportion of carbohydrates which in the other ration was replaced by a corresponding proportion of fat. The question is, whether there was any difference in the total quantities of energy transformed and in the drafts which the body made upon its previously accumulated stores of material to supply its demands for a like amount of energy for muscular work. The data for comparison are here summarized.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 188.

[b] The data for the nitrogen elimination for the three days here under discussion, i. e., April 30, May 1 and 2, 1902, of which the first day was the severe-work experiment No. 55, are given in detail in U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 220.

TABLE 102.—*Efficiency of fats versus carbohydrates in work experiments Nos. 62 and 63 with A. L. L.—Quantities per day.*

Character of experiment.	(*a*) Available energy of food.	(*b*) Energy of body material lost.	(*c*) Energy of total material oxidized.	(*d*) Apparent deficiency with fat diet.	(*e*) Energy of fats and carbohydrates replacing each other.	Per cent efficiency of energy.	
						(*f*) Of fat diet vs. carbohydrate diet.	(*g*) Of fats vs. carbohydrates.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*	*Per cent.*
No. 62, carbohydrate diet	4,276	476	4,752	179	1,680	95.9	89.4
No. 63, fat diet	4,407	524	4,931				

Although there was considerable more available energy in the fat diet (column *a*) a larger amount of energy was derived from body material (column *b*), so that the total energy from material oxidized in the body (column *c*) was 179 calories larger with the fat diet than with the carbohydrate diet. This apparent deficiency of the fat diet is 4.1 per cent of the average amount of available energy in both diets, which substracted from 100 would indicate that the fat diet was but 95.9 per cent as efficient as the carbohydrate diet.

The amount of energy of the fats and carbohydrates replacing each other in the diet averaged 1,680 calories. This is ascertained from the data in Table 99. In experiment No. 62 the total heat of combustion of the fat of the food was 1,066 calories, and that of the carbohydrates 2,968 calories; whereas in experiment No. 63 the potential energy of the food fat was 2,778 calories, and that of the carbohydrates 1,319 calories. The total energy of the fat of the food was therefore 1,712 calories larger, and that of the carbohydrates 1,649 calories smaller, in experiment No. 63 than in No. 62, the average of the two values, 1,680 calories, being assumed as the quantity of replacement. If the difference in efficiency noted in the two diets be ascribed wholly to the fat, the relative or percentage efficiency of the fat as compared to the carbohydrate of the diet would be found by dividing the 179 calories deficiency by the 1,680 calories of replacement and substracting the quotient from 100. According to the figures given in column *g* the fat would be but 89.4 as efficient as the carbohydrate as the source of energy for muscular work.

It is interesting to note that the values here found, which are based upon considerably more accurate data than those in the previous report,[a] show even a wider discrepancy between fat and carbohydrate in a diet for muscular work. Whether the results of the earlier experiments were influenced by errors which were enumerated and discussed in the previous report, or whether the differences are due to variations in the subject or diet, the results here discussed do not of course show. The results here reported are not entirely free from error. The deductions here drawn are based on the assumption that the amount of muscular work performed by the subject was the same in both experiments. The measured external work was the same, but the major and minor movements, to which reference has been made on a preceding page, were not necessarily identical, although an effort was made to control them, and variations in these may have had some influence upon the apparent discrepancy here pointed out. In fact, although the discrepancy between the fats and carbohydrates is apparently a measurable one, it is seriously to be questioned whether it is not more apparent than real.

Although experiments Nos. 62 and 63 are especially adapted for a consideration of the relative efficiencies of fats and carbohydrates in rations for muscular work, it may be interesting to note the available energy of the food and the energy of external muscular work, of the material oxidized in the body, and of body material gained or lost in all the work experiments here reported with both fat and carbohydrate diet. The results are shown in Table 103.

TABLE 103.—*Relative efficiency of fats and carbohydrates in rations for muscular work—Quantities per day.*

Subject and kind of experiment.	Duration.	Available energy of food.	Energy of external muscular work.	Energy of material oxidized.	Energy of body material gained (+) or lost (−).
	Days.	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Experiment No. 56, subject J. C. W., fat diet	3	5,118	569	5,141	− 23
Experiment No. 57, subject, J. C. W., carbohydrate diet	3	5,136	602	5,459	− 323
Experiment No. 61, subject, B. F. D., carbohydrate diet	1	3,315	419	4,463	−1,148
Experiment No. 62, subject, A. L. L., carbohydrate diet	3	4,276	459	4,752	− 476
Experiment No. 63, subject, A. L. L., fat diet	3	4,407	459	4,931	− 524
Experiment No. 64, subject, A. L. L., fat diet	1	5,055	957	7,185	−2,130
Average for experiments Nos. 57 and 62, carbodrate diet	6	4,706	531	5,106	− 400
Average for experiments Nos. 56 and 63, fat diet	6	4,763	514	5,036	− 273
Average for all 3 experiments, carbohydrate diet	7	4,507	515	5,014	− 506
Average for all 3 experiments, fat diet	7	4,804	577	5,343	− 539

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 185.

In view of the differences in the amounts of available energy from food and in those from material actually oxidized, specific deductions are not warranted. One point, however, is of interest. If the average results of the three experiments made with different subjects on carbohydrate diet are compared with those of the corresponding experiments with fat diet, the discrepancies between the available energy of food, the energy of external muscular work and energy of material oxidized practically counterbalance; but with the carbohydrate diet there was 507 calories of energy from body materials, and 539 calories with the fat diet. This would imply that the carbohydrates were slightly more efficient as sources of energy for muscular work, which is in direct opposition to the deductions from the results of experiments Nos. 56 and 63 taken together, as compared with experiments Nos. 57 and 62, but is in harmony with those from experiment No. 62 as compared with No. 63. In all probability the results of experiments Nos. 62 and 63 are more directly comparable than any averages of experiments differing so widely in conditions; therefore the deductions previously drawn from the results of these two experiments seem to warrant the belief that fats are possibly slightly inferior to carbohydrates as sources of energy for muscular work.

VENTILATION.

The results of many of the experiments with the respiration calorimeter, both in its early and in its present form, are of considerable significance in a consideration of the general subject of ventilation, and it seems fitting, therefore, that the data of such character obtained with the apparatus should be discussed. Inasmuch as this topic has not received especial attention in previous publications of this Office, data obtained with the earlier form of apparatus will be included in this discussion, although the most striking experiments were made with the new form of apparatus.

NORMAL PERCENTAGE OF CARBON DIOXID IN ATMOSPHERIC AIR.

Since carbon dioxid is a product of respiration, and results from the combustion of illuminating gas and the fuel of ordinary heating appliances, it is not at all surprising that the proportion found in air has long been considered an index of the degree of purity of the air. Furthermore, the determination of carbon dioxid is accomplished with greater ease and with much simpler apparatus than is the case with the determination of the other three ingredients of the atmosphere. At first sight the determination of the moisture content of the air by means of a sling psychrometer might appear much simpler than the estimation of the amount of carbon dioxid even by the hand apparatus of Wolpert. The amount of water vapor, however, fluctuates widely, whereas the carbon dioxid content of normal air is practically a constant. Since normal air contains a relatively definite quantity of carbon dioxid, and the methods for determining this are extremely simple and may be carried out with portable apparatus, estimations of carbon dioxid can be readily taken as an index to the degree of vitiation of the air.

Most writers state that the percentage of carbon dioxid in normal atmospheric air is 4 parts by volume in 10,000. This proportion has been derived chiefly from analyses of air taken in large cities, where there would be an undue contamination of the air with carbon dioxid, both from the lungs and also from the enormous quantities of fuel consumed. The proportion found as a result of several thousand analyses of normal air at Middletown is only 3 parts by volume per 10,000, which is more nearly in accord with the result of the best recent work. Russell,[a] in an article on the atmosphere in relation to human life and health, expresses surprise that the older value, 4 parts per 10,000, is still so almost universally taken as a standard when 3 parts per 10,000 is more strictly in accord with actual observations.

No analyses of external air were made in the experiments with the present form of respiration calorimeter. In those with the earlier form, the air current for ventilating the respiration chamber was drawn from outside the laboratory through a metal pipe extending beyond the walls of the building. Just before it entered the respiration chamber a sample of the air was withdrawn through a small pipe connected with the large one, and was passed through U-tubes containing pumice stone drenched with sulphuric acid to remove water, and specially prepared soda lime to remove carbon dioxid. The air sample was withdrawn by means of a series of aspirators of a capacity of 150 liters each. As the air was caused to flow through the U-tubes at a rate of about 400 cubic centimeters per minute, about five hours were required to take each sample of 150 liters. As soon as one sample was taken, another aspirator was immediately started, consequently the air was withdrawn and analyzed continuously for twenty-four hours of the day and from four to ten or twelve consecutive days.

The quantity of carbon dioxid removed by the U-tube connected with each aspirator was ascertained from the increase in the weight of the tube. The recorded volume of the aspirator was, in each case, reduced to standard conditions, i. e., a temperature of 0° and a pressure of 760 millimeters of mercury. The results of the analyses of air were expressed in milligrams of carbon dioxid per liter of air. The average of a large number of such analyses is 0.6 milligram per liter, which is equivalent to very close to 3 volumes of carbon dioxid per

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[a] Smithsn. Misc. Collect., 1072 (1896), p. 11.

10,000 volumes of air. Fluctuations in the amount of carbon dioxid corresponding to those reported by other investigators were frequently noted, variations of great magnitude, relatively speaking, being observed on foggy days and on days when the wind blew from the factory portion of the city. The laboratory is located on the western side of the city and there are comparatively few buildings and no factories to the west of the laboratory. The prevailing winds vary from southwest to northwest, consequently the air passes for the most part over a district free from houses or factories, although in the immediate vicinity of the laboratory there are a number of college buildings.

IMPURE AIR.

Of the many sources of carbon dioxid in the air the problem of ventilation, generally speaking, has to do with but two—first, the products of respiration of men and animals, and, second, the products of combustion of fuel. In the second instance the combustion is supposed to yield ordinarily only carbon dioxid and water, while the products of respiration of men and animals have commonly been thought to contain certain volatile concomitant impurities, possibly of the nature of amins or of alkaloidal products. Earlier investigators, however, considered the carbon dioxid decidedly toxic "per se." Without doubt, in the large majority of cases the actual amount present has been grossly exaggerated. History has given us at least two tragic results of bad ventilation, namely, the imprisonment of 146 persons in the Black Hole of Calcutta and the confinement of 300 men in an underground room after the battle of Austerlitz. The death of practically every individual in both instances leaves no doubt as to the absolute danger to life of poor ventilation. These two calamities have frequently been cited as indicating the presence of a specific toxic poison in expired air, and the same theory has led to the promulgation of the doctrine that the discomfort felt in badly ventilated rooms is due to the presence of volatile ptomaines in expired air.

Experiments of Brown-Sequard and D'Arsonval announcing the presence of ptomaines in expired air soon drew the attention of other investigators, but in general a repetition of their experiments gave negative results. A most elaborate and painstaking series of experiments was made by Billings, Mitchell, and Bergey,[a] which fail at every point to distinguish the presence of a volatile organic poison in human breath. The conclusion is reached that the acute effects of poor ventilation are the same in man as in animals—that is, asphyxiation due to excessive carbon dioxid, and the authors consider the discomfort noticed in a poorly ventilated room a result in general of high temperature and unpleasant odors which arise from the body. The slight increase in the percentage of carbon dioxid occurring in the air of poorly ventilated rooms has, according to their conclusions, no effect whatever on the comfort of the occupants. The bibliography of the subject given in their memoir is very complete up to the date of publication (1896).

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[a] Smithsn. Contrib. Knowl., vol. 29, No. 980, p. 81.

VENTILATION OF THE RESPIRATION CHAMBER.

Ventilation experts, relying largely on the standards established by Pettenkofer, demand that each person be furnished 3,000 cubic feet of fresh air per hour. In constructing the respiration calorimeter at Middletown the problem of ventilation was a serious one. The chamber, which is 7 feet (2.15 meters) long, 6 feet (1.92 meters) high, and 4½ feet (1.22 meters) wide, has a cubical content of approximately 4,800 liters. To maintain an air current sufficient to supply 3,000 cubic feet, or 85,000 liters, of pure air per hour would require the complete change of air in the apparatus about every four minutes, which was impracticable. During some preliminary experimenting it was found that persons could remain several hours in the air-tight chamber with no air passing through it, with no special discomfort other than that produced by a rise in temperature. When a cooling system was introduced to remove the heat and keep the temperature comfortable, the absence of ventilation was not noticeable for several hours longer, although no experiments were made to determine absolutely at what time discomfort would be experienced. In fact, in all the tests made with the apparatus after cooling appliances were provided no discomfort was at any time felt; consequently experiments were made to determine the effect of a small ventilation, with provisions to increase it if necessary.

An air pump was so adjusted as to draw about 100 liters of air per minute through the apparatus, an amount only one-twelfth of that required by authorities on ventilation. No discomfort was felt by the subject after a sojourn of a number of hours in the apparatus with this rate of ventilation. The first extended experiment was made with a subject who fortunately did not realize the nature of the test. He slept with his accustomed regularity, and no abnormal conditions of any kind developed during the night. In the morning after the first night in the chamber he was so well and contented that the experiment was continued two and one-half days without interruption or break of any kind. His health was not only excellent when he came out, but continued so. A second experiment of equal length was made, with equally satisfactory results.

The third experiment was carried on with a different subject, who had assisted in those preceding. The rate of ventilation was reduced from 100 to 75 liters per minute. The subject was not aware of this reduction and believed that he was receiving the full amount of the previous experiments. This experiment continued for five days, and at the end the subject felt perfectly well and ready to repeat the experiment.

For the fourth experiment another assistant volunteered as subject, and a much more elaborate test was planned, to continue unbroken for twelve days. Heretofore both subjects had been at rest, but in this case the subject was to devote his time during the first part of the experiment to intense mental work; during the second period he was to remain as quiet as possible, and during the last period he was to engage in severe muscular work. Unknown to the subject the ventilating air current was reduced to 55 liters per minute shortly after the experiment began. According to the results of the previous experiments no trouble was to be anticipated during the first and second periods of the experiment, when the muscular activity was small, but with increased carbon dioxid production accompanying the hard muscular work a complaint of insufficient ventilation might be expected. However, in spite of the fact that the daily carbon dioxid production rose from 800 grams on the days of rest to 1,400 grams on the days of work and remained at that amount for three successive days, no discomfort was felt by the subject. As a result of these tests a new form of pump was installed, the so-called Blakeslee meter pump, described in previous publications of this Office.[a] Provision was made for a maximum ventilation of 75 liters per minute, and this rate was used in all experiments with the respiration apparatus in its earlier form.

The exact conditions regarding the ventilation of the respiration chamber during an experiment are as follows: The subject, a normal, healthy man, living on a diet approximately sufficient to maintain his body in carbon and nitrogen equilibrium, enters the respiration chamber at about 11 p. m. As soon as the large sheet of glass used to seal the window through which he enters is securely cemented in place, thus making the whole apparatus air-tight, the air pump is started and a continuous current of air, drawn at the rate of 75 liters per minute, is maintained during the whole experiment. Before the subject enters the chamber the furniture, bedding, dishes, clothes, and incidental apparatus are put in place, this generally being done by an assistant who enters the chamber and takes the articles from a second assistant who passes them through the window. During this half hour's occupancy of the chamber no ventilation is maintained other than that afforded by the window; therefore it is probable that at the moment he enters the chamber for an experiment the subject is surrounded by a very much vitiated atmosphere so far as regards the amount of carbon dioxid.

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[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 63, p. 31, and 136, p. 20.

After arranging the bed and furniture for the night, the subject retires at 11 o'clock. Save for the novelty the subjects usually experience no difficulty in sleeping well, there being no discomfort, headache, or stifling sensation of any kind. At 7 a. m. a sample of the air is analyzed, and, in general, 8 milligrams of carbon dioxid per liter are found to be present. Since the carbon dioxid in normal air is 0.6 milligram per liter, the air in which the subject has been sleeping all night therefore contains thirteen times the normal content of carbon dioxid.

AMOUNTS OF CARBON DIOXID IN THE AIR IN THE CHAMBER.

In the earlier experiments the analyses of the air residual in the chamber were made only about once every six hours, but in the more recent experiments the residual amounts of carbon dioxid and water are determined every two or three hours.

When the air is analyzed, the residual amounts of carbon dioxid are directly determined. The amount present in the air at other times may be computed from the total weight of carbon dioxid produced, the rate of ventilation, and the time. Such computations show that during an early morning period—3 a. m. to 5 a. m.—when the carbon dioxid production is generally at its lowest, the amount present will be found in general to be 7 milligrams per liter, or over eleven times the standard of 0.6 milligram per liter. On one occasion, following a 36-hour fast, the carbon dioxid content of the air during this period was found to be 5 milligrams per liter or eight times normal. This is, with the exception of a special experiment to be reported beyond, the lowest amount ever recorded.[a] It is evident, then, that even during that portion of the day which by reason of decreased carbon dioxid production is most favorable for good ventilation, the atmosphere is, relatively speaking, very impure as compared with the normal. This condition, which represents the minimum amount of carbon dioxid during the whole experimental period, does not usually continue longer than two or three hours. After rising and dressing the subject is generally quite active muscularly, caring for the bed and bedding, adjusting the table and weighing apparatus, and making observations; and usually it is not until about 7.45 a. m. that he is ready to sit down to breakfast. During a so-called rest experiment, this period, and a similar one just before the subject retires, are perhaps the most active of the day, as the remaining time is generally spent in reading or writing. In these two 2-hour periods the air contains on an average 9.4 milligrams of carbon dioxid per liter, or nearly sixteen times normal. A rest experiment seldom lasts more than five or six days.

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[a] For purposes of comparison with other work it might be more convenient to have the quantities expressed by volume rather than by weight, but the volume per 10,000 may be easily computed by multiplying the number of milligrams per liter by the approximate factor, 5.25. In the last example cited, for instance, 5 milligrams per liter equals about twenty-six volumes per 10,000.

In the work experiment, however, the results are most striking. One of the subjects, J. C. W., who served in many experiments, was an athlete, competing especially in bicycle races. During the work experiments in the respiration calorimeter he rode eight hours per day on a stationary bicycle ergometer. The work was done in periods of two hours each, interspersed with short rests. The carbon dioxid production reached its maximum during the work periods. During one 2-hour work period 8,551 liters of air passed out of the apparatus, carrying with it 313.6 grams of carbon dioxid, or 36.6 milligrams per liter. This is practically 3 per cent by weight of carbon dioxid, and represents 183 volumes per 10,000. In other words, the amount of carbon dioxid in the air of the chamber was sixty-one times as great as exists in outside air. From 8 a. m. to 6.30 p. m. the subject lived in an atmosphere but little purer than this. The experiments continued from five to nine consecutive days.

During the evening hours the large accumulation of carbon dioxid in the residual air of the chamber is gradually swept out by the ventilating air current, and the usual minimum amount is present in the early morning hours. Tabulated results show the immediate fall in carbon dioxid production accompanying a cessation of muscular exercise, and in fact the amount of carbon dioxid eliminated during the last six hours of the night is almost identically the same, whether the night be preceded by a day of rest or a day of hard muscular work. Experiments in which muscular work is performed differ, therefore, from those of rest, so far as concerns composition of the atmosphere inside the chamber, during the day and early evening hours, or about eighteen hours out of the twenty-four. It is during such experiments that we should expect to find any abnormalities of the atmosphere affecting the comfort and health of the subject, if at all. As a matter of fact, every individual who has spent a full day in the calorimeter has not only said that his comfort was unaffected but expressed a willingness to repeat the experiment. All, whether subjects of rest or work experiments, are well, and, so far as we can tell, in no way disposed to disease.

On opening the window of the chamber after an experiment the air inside invariably smells "close" to an outsider, yet it is unnoticed by the subject himself. On several occasions a blood count was made before and after the experiment to determine if an anemic tendency was developed, but in all cases the results were negative. Physically and mentally the subjects are apparently entirely uninfluenced by the long sojourn in the vitiated atmosphere.

MOISTURE CONTENT OF THE AIR CURRENT.

As the carbon dioxid content of normal air is nearly constant, it was thought possible to regulate the one variable constituent of the air—i. e., water vapor—and thus have air of constant composition enter the chamber. If the amount of moisture in the air could be either entirely eliminated or maintained at a fixed point, analyses of the incoming air would be unnecessary. To this end all the air entering the chamber was passed through pipes immersed in cold brine to freeze out the moisture. The brine was kept at low temperature by means of an ammonia refrigerating machine. With this apparatus the moisture content of the air entering the chamber was kept at about 1 milligram per liter.

To aid in the determination of the total amount of water vapor leaving the chamber, the outgoing air was similarly conducted through cans immersed in the cold brine. The larger proportion of the water leaving the chamber was deposited in these cans.

The moisture content of the air in the respiration chamber is dependent upon the dryness of the air entering the chamber, the quantity of water vapor given off from the lungs and skin of the subject, and the temperature of the heat-absorbing device. As expressed above, the air entered the chamber very dry. The quantity of moisture given off by the subject is determined in large measure by the degree of muscular activity; hence it would be largest in the work experiments. But the temperature of the heat-absorbing device in a work experiment is frequently below the dew-point of the air in the chamber, wherefore water is condensed on the absorber, thus tending to reduce the moisture content of the air. During the work experiment there may be a liter or more of water thus condensed each day. The approximate humidity of the air in the chamber, as indicated by a wet and dry bulb hygrometer, was about 75 per cent during the work periods, which was somewhat above normal; but during the periods in which the subject was quieter, more especially at night, it was much lower. The average temperature of the air inside the chamber was practically constant at 20° C.

CONCOMITANT IMPURITIES.

If any of the so-called concomitant impurities were present in the air of the chamber, we might have expected to find them in considerable proportions in the water condensed on the surface of the absorber inside the chamber or in the pipes and cans through which the outgoing air was passed; for though much of the material might pass through the freezing cans uncondensed, it seemed highly probable that a large portion of it would be retained therein with the condensed and frozen water vapor. If there were anything of the kind present this solution should have afforded an excellent medium for studying its toxicity. A large number of experiments were made in which quantities of the liquid condensed on the heat-absorbing system inside the chamber, and also of the liquid condensed in the cans outside, were injected subcutaneously into white rats, but in all cases the results were negative. The water, especially that condensed on the surface of the absorbers inside the chamber, was frequently dusty, but after filtration no toxicity could be detected. This observation is in accord with the experience of Billings, Mitchell, and Bergey.[a]

EXPERIMENTS WITH THE NEW FORM OF APPARATUS.

The new form of respiration apparatus, with which the experiments described in detail in the present bulletin were made, was so constructed as to eliminate the need for the analysis of outside air, and the freezing system was discarded. With this apparatus the air entering the respiration chamber is absolutely dry and free from carbon dioxid, and contains varying percentages of oxygen and nitrogen. The carbon dioxid and water vapor imparted to the air in the chamber by the subject are entirely removed from the air as it is drawn from the chamber, and oxygen to replace that used by the subject is supplied to the air as it is returned to the chamber. The composition of the air in circulation is ascertained by analysis at certain intervals, and with the data obtained it is possible to compute the amount and proportion of oxygen in the air. The data regarding the quantities of oxygen, carbon dioxid, and water vapor in the air of the chamber at different periods of the experiments reported in the present bulletin are summarized in the table below:

TABLE 104.—*Ventilation conditions in chamber at end of period, metabolism experiments, Nos. 56–58 and 60–67.*

Experiment No.	Date.	Period.	Volume of respiration chamber.	Oxygen.		Carbon dioxid.		Water vapor.	
				Liters.	Per cent.	Liters.	Parts per 10,000.	Grams.	Relative humidity.
	1903.		*Liters.*						*Per cent.*
56	Apr. 27–28	1 p. m.	4, 624. 00	882. 19	19. 1	72. 48	157	67. 95	81. 0
		7 p. m.	4, 637. 39	897. 66	19. 4	59. 71	129	68. 82	82. 0
		1 a. m.	4, 640. 97	944. 69	20. 4	24. 63	53	64. 04	76. 3
		7 a. m.	4, 664. 63	967. 44	20. 7	20. 64	44	63. 14	75. 3
	Apr. 28–29	10 a. m.	4, 642. 09	867. 83	18. 7	86. 08	185	66. 02	78. 7
		1 p. m.	4. 654. 28	868. 70	18. 7	76. 90	165	69. 96	83. 4
		4 p. m.	4, 624. 63	836. 01	18. 1	86. 92	188	68. 22	81. 3
		7 p. m.	4, 640. 14	887. 94	19. 1	46. 35	100	64. 97	77. 5
		10 p. m.	4, 642. 63	900. 32	19. 4	27. 07	58	66. 47	79. 3
		1 a. m.	4, 633. 93	891. 78	19. 2	21. 31	46	68. 60	81. 8
		4 a. m.	4, 625. 37	904. 87	19. 6	17. 11	37	68. 71	81. 9
		7 a. m.	4, 627. 88	936. 17	20. 2	19. 42	42	63. 70	75. 9
	Apr. 29–30	10 a. m.	4, 625. 28	862. 28	18. 6	80. 55	174	65. 21	77. 8
		1 p. m.	4, 611. 25	874. 62	19. 0	43. 40	94	66. 30	79. 0
		4 p. m.	4, 598. 66	810. 61	17. 6	87. 07	189	67. 43	80. 4
		7 p. m.	4, 600. 42	835. 47	18. 2	53. 83	117	66. 77	79. 6
		10 p. m.	4, 613. 98	872. 72	18. 9	28. 63	62	62. 62	74. 7
		1 a. m.	4, 598. 60	851. 41	18. 5	22. 89	50	69. 79	83. 2
		4 a. m.	4, 599. 54	854. 54	18. 6	20. 31	44	67. 11	80. 0
		7 a. m.	4, 609. 15	871. 62	18. 9	18. 07	39	60. 37	72. 0
	Average for 3 days.		4, 628. 38	887. 95	19. 2	45. 45	98	66. 26	79. 0

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[a] Loc. cit.

Table 104.—*Ventilation conditions in chamber at end of period, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Experiment No.	Date.	Period.	Volume of respiration chamber.	Oxygen.		Carbon dioxid.		Water vapor.	
				Liters.	Per cent.	Liters.	Parts per 10,000.	Grams.	Relative humidity.
	1903.		*Liters.*						*Per cent.*
57	May 7–8	10 a. m.	4,623.88	956.54	20.7	72.40	157	61.42	73.2
		1 p. m.	4,617.64	938.19	20.3	69.14	150	65.06	77.6
		4 p. m.	4,604.34	901.94	19.6	80.88	176	66.82	79.7
		7 p. m.	4,617.80	925.37	20.0	58.27	126	66.99	79.9
		10 p. m.	4,620.47	944.73	20.5	38.57	83	65.12	77.6
		1 a. m.	4,626.11	936.29	20.2	44.08	95	69.75	83.2
		4 a. m.	4,636.04	948.48	20.5	28.72	62	64.32	76.7
		7 a. m.	4,646.44	990.95	21.3	25.93	56	61.27	73.0
	May 8–9	10 a. m.	4,628.84	899.75	19.4	86.77	187	68.06	81.1
		1 p. m.	4,624.48	917.88	19.9	47.24	102	68.84	82.1
		4 p. m.	4,629.68	886.64	19.2	76.54	165	65.70	78.3
		7 p. m.	4,631.16	891.48	19.3	54.50	118	68.64	81.8
		10 p. m.	4,630.46	921.74	19.9	25.34	55	60.53	72.2
		1 a. m.	4,641.98	928.95	20.0	19.34	42	65.05	77.6
		4 a. m.	4,645.47	889.66	19.2	12.21	26	58.93	70.3
		7 a. m.	4,643.11	923.22	19.9	14.33	31	58.35	69.6
	May 9–10	10 a. m.	4,637.94	820.92	17.7	96.29	208	64.74	77.2
		1 p. m.	4,645.25	810.42	17.4	85.23	184	66.37	79.1
		4 p. m.	4,647.20	779.65	16.8	107.15	231	69.57	82.9
		7 p. m.	4,652.32	863.68	18.6	31.91	69	63.96	76.3
		10 p. m.	4,656.64	868.71	18.7	31.25	67	60.56	72.2
		1 a. m.	4,644.19	864.26	18.6	17.08	37	62.68	74.7
		4 a. m.	4,650.68	870.03	18.7	18.52	40	59.09	70.5
		7 a. m.	4,650.23	878.26	18.9	14.66	32	57.52	68.6
	Average for 3 days		4,635.51	898.24	19.4	48.18	104	64.14	76.5
58	Nov. 10–11	1 p. m.	4,646.65	854.92	18.4	50.12	108	51.66	61.6
		7 p. m.	4,644.34	845.98	18.2	57.41	124	49.50	59.0
		1 a. m.	4,648.09	849.12	18.3	58.16	125	48.24	57.5
		7 a. m.	4,649.17	853.41	18.4	49.91	107	50.15	59.8
	Nov 11–12	1 p. m.	4,649.91	865.23	18.6	43.28	93	43.78	52.2
		7 p. m.	4,632.55	874.64	18.9	16.82	36	41.40	49.4
		1 a. m.	4,624.58	846.24	18.3	37.20	80	39.76	47.4
		7 a. m.	4,629.41	876.07	18.9	13.42	29	36.07	43.0
	Nov. 12–13	1 p. m.	4,638.52	853.59	18.4	45.85	99	34.01	40.6
		7 p. m.	4,652.16	881.26	18.9	24.33	52	36.63	43.7
		1 a. m.	4,650.65	850.74	18.3	51.97	112	35.52	42.3
		7 a. m.	4,643.69	859.56	18.5	33.33	72	35.38	42.2
	Average for 3 days		4,642.48	859.23	18.5	40.15	86	41.84	49.9
	1904.								
	Jan. 26–27 (preliminary to experiment No. 60)	11 p. m.	4,623.05	962.12	20.8	2.99	6	33.61	40.1
		1 a. m.	4,619.31	962.47	20.8	1.16	3	30.82	36.7
		4 a. m.	4,631.09	976.46	21.1	.82	2	27.96	33.3
		7 a. m.	4,645.60	992.78	21.4	.95	2	25.73	30.7
	Average of preliminary periods		4,629.76	973.46	21.0	1.48	3	29.53	35.2
60	Jan. 27–28	10 a. m.	4,664.00	991.54	21.3	4.12	9	31.84	38.0
		1 p. m.	4,668.74	997.77	21.4	3.76	8	29.19	34.8
		4 p. m.	4,680.99	1,006.99	21.5	4.25	9	30.13	35.9
		7 p. m.	4,697.47	1,019.43	21.7	8.06	17	28.88	34.4
		10 p. m.	4,711.23	1,030.65	21.9	6.34	13	29.74	35.5
		1 a. m.	4,732.01	1,056.73	22.3	5.83	12	24.29	29.0
		4 a. m.	4,731.33	1,058.65	22.4	3.74	8	22.68	27.0
		7 a. m.	4.729.85	1,056.10	22.3	4.90	10	21.48	25.6
	Jan. 28–29	10 a. m.	4,738.83	984.38	20.8	55.92	118	45.72	54.5
		1 p. m.	4,721.66	926.81	19.6	91.58	194	48.83	58.2
		4 p. m.	4,713.94	903.37	19.2	103.71	220	51.43	61.3
		7 p. m.	4,712.66	901.27	19.1	100.89	214	52.70	62.8
		10 p. m.	4,710.27	886.40	18.8	112.95	240	51.96	62.0
		1 a. m.	4,701.02	881.74	18.8	106.89	227	51.78	61.7
		4 a. m.	4,684.59	865.88	18.5	103.68	221	53.14	63.4
		7 a. m.	4,676.64	845.10	18.1	112.88	240	55.69	66.4
	Jan. 29–30	10 a. m.	4,681.46	892.13	19.1	75.73	162	47.72	56.9
		1 p. m.	4,669.35	932.79	20.0	22.48	48	43.47	51.8
		4 p. m.	4,664.72	905.50	19.4	40.54	87	46.36	55.3
		7 p. m.	4,658.92	919.83	19.7	19.93	43	44.22	52.7
		10 p. m.	4,657.22	891.93	19.2	42.81	92	45.37	54.1

TABLE 104.—*Ventilation conditions in chamber at end of period, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Experiment No.	Date.	Period.	Volume of respiration chamber.	Oxygen.		Carbon dioxid.		Water vapor.	
				Liters.	Per cent.	Liters.	Parts per 10,000.	Grams.	Relative humidity.
	1904.		*Liters.*						*Per cent.*
60	Jan. 29–30	1 a. m.	4, 650. 34	916. 75	19. 7	12. 51	27	42. 26	50. 4
		4 a. m.	4, 655. 57	924. 42	19. 9	12. 46	27	38. 65	46. 1
		7 a. m.	4, 662. 15	930. 29	20. 0	12. 66	27	37. 48	44. 7
	Average for 3 days.		4, 690. 62	946. 94	20. 2	44. 53	95	40. 63	48. 4
61	Jan. 30–31	10 a .m.	4, 667. 21	835. 31	17. 9	80. 13	172	61. 49	73. 3
		1 p. m.	4, 660. 09	840. 35	18. 0	59. 81	128	61. 52	73. 3
		4 p. m.	4, 668. 56	851. 23	18. 2	52. 99	113	61. 96	73. 9
		7 p. m.	4, 662. 41	874. 98	18. 8	26. 06	56	56. 64	67. 5
		10 p. m.	4, 664. 90	886. 95	19. 0	19. 56	42	51. 98	62. 0
		1 a. m.	4, 663. 40	883. 57	19. 0	16. 37	35	54. 53	65. 0
		4 a. m.	4, 665. 50	889. 54	19. 1	16. 40	35	49. 68	59. 2
		7 a. m.	4, 665. 46	891. 29	19. 1	15. 02	32	47. 97	57. 2
	Average for 1 day		4, 664. 69	869. 15	18. 6	35. 79	77	55. 72	66. 4
62	Apr. 16–17	10 a. m.	4, 597. 02	769. 73	16. 7	79. 45	173	65. 76	78. 4
		1 p. m.	4, 616. 94	821. 97	17. 8	48. 69	105	55. 53	66. 2
		4 p. m.	4, 629. 13	801. 19	17. 3	65. 79	142	60. 63	72. 3
		7 p. m.	4, 645. 71	835. 93	18. 0	40. 75	88	57. 85	69. 0
		10 p. m.	4, 662. 55	868. 13	18. 6	24. 80	53	52. 25	62. 3
		1 a. m.	4, 668. 93	859. 56	18. 4	18. 30	39	65. 25	77. 8
		4 a. m.	4, 675. 63	874. 34	18. 7	15. 80	34	55. 89	66. 6
		7 a. m.	4, 681. 21	876. 75	18. 7	14. 58	31	55. 59	66. 3
	Apr. 17–18	10 a. m.	4, 677. 40	785. 48	16. 8	78. 76	168	67. 99	81. 1
		1 p. m.	4, 676. 49	813. 42	17. 4	47. 67	102	63. 05	75. 2
		4 p. m.	4, 666. 84	775. 65	16. 6	67. 75	145	62. 78	74. 9
		7 p. m.	4, 667. 00	794. 25	17. 0	43. 31	93	60. 35	72. 0
		10 p. m.	4, 672. 23	814. 38	17. 4	26. 60	57	56. 98	67. 9
		1 a. m.	4, 666. 67	806. 98	17. 3	18. 11	39	61. 31	73. 1
		4 a. m.	4, 659. 78	806. 46	17. 3	16. 15	35	54. 03	64. 4
		7 a. m.	4, 658. 81	805. 10	17. 3	16. 22	35	50. 73	60. 5
	Apr. 18–19	10 a. m.	4, 653. 86	745. 10	16. 0	80. 83	174	67 03	79. 9
		1 p. m.	4, 645. 38	755. 46	16. 3	58. 16	125	63. 44	75. 6
		4 p. m.	4, 631. 87	751. 01	16. 2	76. 98	166	64. 77	77. 2
		7 p. m.	4, 625. 97	769. 94	16. 6	47. 19	102	62. 14	74. 1
		10 p. m.	4, 622. 77	782. 14	16. 9	33. 11	72	57. 23	68. 2
		1 a. m.	4, 626. 00	793. 01	17. 1	20. 18	44	57. 74	68. 8
		4 a. m.	4, 615. 51	777. 36	16. 8	20. 75	45	58. 74	70. 0
		7 a. m.	4, 613. 92	776. 52	16. 8	17. 58	38	57. 29	68. 3
	Average for 3 days.		4, 648. 23	802. 49	17. 3	40. 73	88	59. 76	71. 2
63	Apr. 19–20	10 a. m.	4, 608. 75	718. 03	15. 6	82. 35	179	70. 91	84. 5
		1 p. m.	4, 613. 98	754. 86	16. 4	48. 26	105	65. 88	78. 5
		4 p. m.	4, 601. 92	723. 12	15. 7	65. 21	142	63. 23	75. 4
		7 p. m.	4, 617. 32	766. 12	16. 6	33. 70	73	60. 38	72. 0
		10 p. m.	4, 620. 84	778. 35	16. 8	23. 60	51	58. 16	69. 3
		1 a. m.	4, 614. 37	771. 98	16. 7	17. 76	39	60. 12	71. 7
		4 a. m.	4, 609. 82	767. 49	16. 6	16. 30	35	58. 69	70. 0
		7 a. m.	4, 601. 70	754. 62	16. 4	15. 36	33	61. 00	72. 7
	Apr: 20–21	10 a m.	4, 595. 92	702. 81	15. 3	75. 39	164	71. 63	85. 4
		1 p. m.	4, 598. 33	732. 64	15. 9	48. 44	105	63. 16	75. 3
		4 p. m.	4, 600. 18	758. 95	16. 5	59. 21	129	63. 24	75. 4
		7 p. m.	4, 602. 05	777. 28	16. 9	36. 22	79	62. 14	74. 1
		10 p. m.	4, 614. 87	851. 78	18. 5	22. 88	50	57. 57	68. 6
		1 a. m.	4, 626. 53	856. 90	18. 5	19. 30	42	61. 36	73. 2
		4 a. m.	4, 636. 84	874. 77	18. 9	13. 79	30	55. 51	66. 2
		7 a. m.	4, 643. 39	865. 16	18. 6	16. 77	36	62. 65	74. 7
	Apr. 21–22	10 a. m.	4, 658. 35	855. 85	18. 4	69. 65	150	70. 14	83. 6
		1 p. m.	4, 662. 88	881. 71	18. 9	44. 39	95	65. 42	78. 0
		4 p. m.	4, 662. 59	905. 07	19. 4	61. 59	132	65. 68	78. 3
		7 p. m.	4, 675. 77	940. 42	20. 1	35. 35	76	61. 29	73. 1
		10 p. m.	4, 689. 73	1, 012. 66	21. 6	23. 06	49	56. 80	67. 7
		1 a. m.	4, 703. 11	1, 019. 65	21. 7	18. 32	39	61. 23	73. 0
		4 a. m.	4, 704. 50	1, 021. 37	21. 7	19. 41	41	55. 77	66. 5
		7 a. m.	4, 713. 87	1, 033. 12	21. 9	15. 76	33	52. 44	62. 5
	Average for 3 days.		4, 636. 57	838. 53	18. 1	36. 75	79	61. 85	73. 7

Table 104.—*Ventilation conditions in chamber at end of period, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Experiment No.	Date.	Period.	Volume of respiration chamber.	Oxygen.		Carbon dioxid.		Water vapor.	
				Liters.	Per cent.	Liters.	Parts per 10,000.	Grams.	Relative humidity.
	1904.		*Liters.*						*Per cent.*
64	Apr. 22–23	10 a. m.	4,718.11	990.47	21.0	80.14	170	70.03	83.5
		1 p. m.	4,715.41	1,017.10	21.6	46.81	99	66.77	79.6
		4 p. m.	4,703.77	976.15	20.8	66.75	142	69.55	82.9
		7 p. m.	4,714.29	1,007.64	21.4	45.88	97	63.77	76.0
		10 p. m.	4,715.68	970.01	20.6	70.18	149	71.49	85.2
		1 a. m.	4,719.06	1,007.14	21.3	33.92	72	65.53	78.1
		4 a. m.	4,721.77	1,012.89	21.5	31.40	67	61.40	73.2
		7 a. m.	4,724.86	1,028.45	21.8	17.13	36	60.39	72.0
	Average for 1 day		4,716.62	1,001.23	21.3	49.03	104	66.12	78.8
65	Apr. 23–24	10 a. m.	4,723.24	1,015.95	21.5	19.14	41	63.03	75.1
		1 p. m.	4,715.42	1,015.76	21.5	16.34	35	55.92	66.7
		4 p. m.	4,713.06	1,001.78	21.3	19.59	42	60.23	71.8
		7 p. m.	4,709.50	1,003.80	21.3	16.99	36	54.74	65.3
		10 p. m.	4,705.64	991.71	21.1	21.21	45	55.10	65.7
		1 a. m.	4,702.71	979.64	20.8	21.64	46	58.82	70.1
		4 a. m.	4,694.91	975.50	20.8	16.89	36	56.55	67.4
		7 a. m.	4,694.36	979.78	20.9	15.01	32	51.66	61.6
	Average for 1 day		4,707.36	995.49	21.2	18.35	39	57.01	68.0
66	Apr. 24–25	10 a. m.	4,688.89	961.85	20.5	22.83	49	52.46	62.5
		1 p. m.	4,674.84	946.90	20.3	22.07	47	50.71	60.5
		4 p. m.	4,665.72	939.72	20.1	21.64	46	47.48	56.6
		7 p. m.	4,658.38	928.05	19.9	23.89	51	46.99	56.0
		10 p. m.	4,648.68	918.76	19.8	20.86	45	47.46	56.6
		1 a. m.	4,646.39	915.77	19.7	18.85	41	47.52	56.7
		4 a. m.	4,622.64	891.86	19.3	15.42	33	48.44	57.8
		7 a. m.	4,615.62	882.50	19.1	18.80	41	46.14	55.0
	Average for 1 day		4,652.65	923.18	19.8	20.55	44	48.40	57.7
67	Apr. 25–26	10 a. m.	4,607.19	852.73	18.5	32.62	71	49.59	59.1
		1 p. m.	4,592.98	840.36	18.3	26.34	57	50.39	60.1
		4 p. m.	4,590.22	832.38	18.1	28.95	63	50.40	60.1
		7 p. m.	4,595.69	839.10	18.3	26.56	58	48.31	57.6
		10 p. m.	4,605.53	854.18	18.5	22.79	50	44.70	53.3
		1 a. m.	4,606.99	846.51	18.4	22.98	50	49.52	59.0
		4 a. m.	4,610.33	854.05	18.5	17.60	38	48.25	57.5
		7 a. m.	4,622.71	865.82	18.7	18.72	41	45.48	54.2
	Apr. 26–27	10 a. m.	4,625.37	887.19	19.2	34.96	76	47.56	56.7
		1 p. m.	4,627.24	887.10	19.2	32.02	69	47.73	56.9
		4 p. m.	4,621.33	868.18	18.8	36.71	79	51.22	61.1
		7 p. m.	4,642.03	895.74	19.3	32.40	70	46.20	55.1
		10 p. m.	4,650.38	904.51	19.5	27.91	60	46.87	55.9
		1 a. m.	4,652.52	902.78	19.4	27.24	59	47.95	57.2
		4 a. m.	4,651.97	905.94	19.5	21.84	47	47.21	56.3
		7 a. m.	4,659.26	913.56	19.6	22.26	48	44.64	53.2
	Average for 2 days		4,622.61	871.88	18.8	26.99	58	47.88	57.1
	Average of all experiments		4,651.92	886.41	19.1	39.33	85	56.16	67.0

The quantity of oxygen in the system is expressed both in liters and in the percentage of the total volume of air in the chamber. The carbon dioxid is likewise expressed in liters and in parts per ten thousand, as is customary in reporting the analysis of atmospheric air. The water vapor is expressed in grams, and from this the percentage of saturation or relative humidity has been computed. In calculating the proportions of oxygen and carbon dioxid the volume used, as shown for the different periods in the first column of figures, is that for the chamber under the usual conditions of temperature and pressure reduced to correspond with a temperature of 0° and a pressure of 760 millimeters. In computing the relative humidity, however, the factor used as a basis for the calculation is that for the quantity of water vapor—17.118 grams[a]—in 1,000 liters of saturated air at a temperature of 20°. It was therefore assumed for convenience in this computation that the temperature of the chamber was uniformly 20° and its volume 4,900 liters. According to the factor used, the 4,900 liters would contain 83.88 grams of water vapor. The amount actually found in the chamber for the first period, for example, was 67.95 grams; hence the percentage of saturation was 81.

It would have been interesting to have similar data for all the previous experiments reported in the earlier publications, and, indeed, data are available for computing the carbon dioxid and water vapor, but it is unnecessary to include these figures in this discussion since there is a sufficient number of experiments conducted under so many varied conditions as to give the minimum and maximum atmospheric conditions inside the respiration chamber under all experimental conditions.

PERCENTAGE OF OXYGEN IN THE AIR OF THE CHAMBER.

The percentage of oxygen in normal air is 20.9.[b] It sometimes varies a trifle, but in general it is very constant. In the previously mentioned large number of analyses of atmospheric air made in the vicinity of this laboratory the variations from this percentage are indeed slight. It is seen, on examination of the table, that the percentage of oxygen in the air in the respiration chamber varies, however, relatively speaking, very markedly, the range in the experiments here reported being from 22.4 in the period ending at 4 a. m. January 28, in experiment No. 60, to 15.3 in the period ending at 10 a. m. April 20, in experiment No. 63.

In general, the percentage of oxygen, while varying with each experiment, is considerably lower than normal. Thus in experiment No. 56 the average percentage was 19.2; in experiment No. 57, 19.4; experiment No. 58, 18.5; experiment No. 60, 20.2; experiment No. 61, 18.6; experiment No. 62, 17.3; experiment No. 63, 18.1; experiment No. 64, 21.3; experiment No. 65, 21.2; experiment No. 66, 19.8; experiment No. 67, 18.8. The cause for these relatively wide fluctuations lies chiefly in the conditions under which oxygen is admitted to the respiration chamber. At the beginning of an experiment the atmosphere in the chamber is somewhat charged with carbon dioxid, but probably not very deficient in oxygen. The subsequent admission of oxygen is determined by two factors: First, the actual amount consumed by the subject inside the respiration chamber, and second, the fluctuations in barometric pressure. The respiration chamber may be likened to the bulb of a large air thermometer in which the temperature is kept very constant, but the fluctuations in barometric pressure alter very materially the absolute volume of air confined in the closed circuit. If the barometer rises, the air in the system will become compressed, the rubber diaphragms on top of the pans will sink, and it will be necessary to introduce oxygen to keep the volume of air in the system nearer that at normal atmospheric pressure. As a result of a marked or rapid rise in barometer, very considerable quantities of oxygen would be admitted, and obviously in the experiments where the percentage of oxygen is above normal there must have been a marked rise in barometer during the progress of the experiment. On the other hand, if the barometer falls rapidly the air inside the closed circuit will expand and no oxygen will be introduced, the subject simply drawing upon the reserve supply in the residual amount present. Under these conditions the percentage of oxygen in the air in the chamber may fall very considerably. The lowest percentages of oxygen have been found in the fasting experiments, the results of which are published elsewhere.[a] The subject of that series remained inside the respiration chamber for thirteen days and fourteen nights, with a marked alteration in atmospheric conditions, but without the slightest apparent discomfort that could be in any wise attributed to the deficiency of oxygen.

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[a] Smithsn. Physical Tables, 1903, Table 168, p. 155.

[b] Smithsn. Contrib. Knowl., 1033 (1896), p. 14.

PERCENTAGE OF CARBON DIOXID IN THE AIR OF THE CHAMBER.

The quantity of carbon dioxid in the air of the chamber is affected by the rate of production from the body of the subject and the rate of ventilation. Although fluctuations in barometric pressure produce wide variations in the oxygen content of the air in the chamber, in determining the residual amount of carbon dioxid atmospheric pressure is of much less importance, and can for the purposes of this discussion be eliminated.

The more rapid the rate of ventilation the more rapidly the produced carbon dioxid is removed from the chamber and absorbed in the purifiers. In these experiments the rate of ventilation was not far from constant, though there were slight differences, and the experiments are not strictly comparable for this reason. Experiments Nos. 62 to 67, however, can be considered as being made with practically the same rate of ventilation.

It is apparent, then, that the determining factor regarding the quantity of carbon dioxid remaining in the air in the chamber is the amount produced by the subject. Since this is directly proportional to the muscular activity, we should expect to find that at the end of the periods in which the subject had been quiet the quantity of carbon dioxid would be small and at the end of periods where there had been excessive muscular activity the amount of carbon dioxid would be large. Attempts were made to keep the muscular activity in different portions of this long series of experiments uniform, although, as already explained, considerable difficulty is found in securing absolute uniformity from day to day even in experiments which are supposed to be duplicates. On the other hand, the degree of muscular activity through the night period is, in general, very constant, and we would expect to find that at the end of each experimental day—i. e., 7 a. m.—the amount of carbon dioxid remaining in the respiration chamber would be fairly constant; and since the total apparent volume of air in the chamber is constant, the quantity of carbon dioxid expressed in parts per 10,000 should not show wide variations. In experiment No. 56 on the three mornings the amount of carbon dioxid was respectively 44, 42, and 39 parts per 10,000. Wider fluctuations were observed in experiments Nos. 57, 58, and 60. In experiments Nos. 62 to 67 the quantity remaining in the chamber at 7 a. m. approximated 17 liters, or about 37 parts per 10,000, varying slightly from day to day.

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[a] Carnegie Inst. Washington Pub. No. 77.

The amount at 7 a. m. is in general the minimum amount for the day, as this period has been preceded by practically a six or eight hour period of sleep. It is interesting to note that during the greater number of days of these experiments the minimum amount of carbon dioxid was about 35 to 37 parts per 10,000, which means that during the experiments here reported the subjects were living in an atmosphere with a carbon dioxid content generally more than twelve times normal. At the end of work periods the amount remaining in the chamber is very much larger than at the end of the night period. Aside from the first two days of experiment No. 60, namely, January 27–28 and 28–29, which were made for an especial purpose and are discussed in detail beyond, as high as 107 liters were present in one case at 4 p. m. on May 9 in experiment No. 57. This amount corresponds to 231 parts per 10,000, or nearly eighty times normal. For the twelve hours of each work day the subject lived, in general, in air with an average carbon dioxid content amounting to considerably over 100 parts per 10,000, or over thirty-three times normal.

Since the quantity of carbon dioxid in the air in the respiration chamber is at times very considerable, it is important to ascertain the effect of such increase on the excretion of carbon dioxid by the subject. There is much evidence, especially from the standpoint of plant physiology, of the possibility of a diminution. In recent years it has been clearly established that the presence of larger or smaller amounts of carbon dioxid in an atmosphere in which plants are growing affects materially the respiratory exchange of the plant.

For example, the work of Brown and Escombe[a] shows that while the photosynthetic power of the plant was enlarged by an increase in the percentage of carbon dioxid, the plants were not stimulated to additional growth. In fact there appeared to be a slight diminution in the quantity of dry matter and a less vigorous development of leaf area, as well as certain morphological differences. Without exception, all the plants experimented with seemed to be best adapted to the atmosphere containing the ordinary proportion of carbon dioxid. The response which they made to slight increases in this amount appeared unfavorable to the growth and reproduction of the plants, and it is believed that the comparatively sudden increase of the carbon dioxid in the air to an extent of but two or three times the present amount would result in the speedy destruction of all plant life.

From considerations such as these it is not difficult to conceive of a disturbance of the respiratory exchange of man as a result of inhaling air containing increased proportions of carbon dioxid and greatly diminished amounts of oxygen, especially since we are coming more and more to believe that the interchange of gases in the alveoli is not so much an effect of diffusion as one which is due more or less to a selective absorptive power of the cells. Indeed Wolpert[b] maintains, as a result of experiments, that the presence of an increased proportion of carbon dioxid in the air results in a diminution of the carbon dioxid excretion in man.

A series of reports by Flügge, Heymann, Paul, and Ercklentz,[c] embodying a large amount of recent research in Flügge's laboratory in Breslau on the problems involved in the question of ventilation, has recently appeared. Prior to this report Formanek[d] had presented an extended review of the previous work on the closely allied subject of the poisonous properties of respired air. In this report he concluded that the presence of ammonia resulting, not from any process of normal metabolism, but from decomposing material in the mouth, especially when the teeth are decayed, is sufficient to account for the poisonous properties which other investigators have found in respired air. Flügge, in reviewing the literature of the subject, points out that the experiments of Brown-Sequard have not been verified by later experimenters, that all the evidence thus far accumulated tends to show that there is no chemical disturbance of the respirable properties of air as a result of contamination by expired air from human beings, and that there is no gaseous emanation resulting from metabolism in men which has the properties of poison. He furthermore concludes that the discomfort and disagreeable results experienced by people living in closed rooms are due principally to disturbances of the elimination of heat by the body, and to bad odors arising from the body and clothing, which though not dangerous to health, are unpleasant, induce psychical disturbances, and consequently should be eliminated as completely as possible.

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[a] Proc. Roy. Soc. (London), 70 (1902), p. 397.

[b] Arch. Hyg., 47 (1903), p. 26.

[c] Ztschr. Hyg. u. Infectionskrank., 49 (1905), p. 363.

[d] Arch. Hyg., 38 (1900), p. 1.

The researches of Heymann on the influence of expired air upon the elimination of carbon dioxid is of special interest in connection with the experiments reported herewith. Dissatisfied with the experimental technique and methods of computation employed by Wolpert, Heymann recalculated a number of Wolpert's experiments, made a number of his own, and arrived at the conclusion that the air immediately surrounding the head of a person has a greater carbon dioxid content than the room air as a whole, and consequently that people frequently breathe air containing relatively large quantities of carbonic acid. These results are accentuated by those in the Breslau laboratory by Paul,[a] who made experiments in a large box in which the carbon dioxid content could be very materially increased. At times the percentage of this gas was many times that in an ordinary room, amounting often to 15 or 16 parts per 1,000. Under this condition of excessive carbon dioxid no discomfort was experienced by the subjects until the humidity also increased. With a humidity of 50 per cent no discomfort was noticed until the temperature had risen to about 26°; on the contrary, if the humidity of the air was 75 to 80 per cent the discomfort was invariably noticed at 24° temperature. Accurate observations of the body temperature were taken at the breast with a delicate thermo element, and measurements of the temperature and humidity of the clothing showed that as soon as the disturbance of the heat evolution of the body began, there was a maximum increase in the temperature of the skin and an increase in the humidity on the covered portions of the body. These objective observations invariably accompanied the subjective disagreeable sensations. Further observations were made which showed that if the body was inclosed in the chamber at a relatively high temperature and with increased moisture, the disagreeable effects persisted even when the inspired air was taken through a tube extending outside the chamber. On the other hand, if the body of the subject was placed outside the chamber, and air which had previously been rendered impure by another person was breathed through a tube in the nose, no discomfort was observed.

Finally, recognizing that invalids, especially in certain classes of disease, are in many cases especially sensitive to impure air, Ercklentz made a number of experiments with patients from the hospital, employing the apparatus that was used by Paul. In the majority of the experiments the carbon dioxid content of the air reached from seven to fifteen parts per thousand. Observations were made regarding the skin temperature and the temperature and moisture of the clothing. These experiments also showed clearly that the chemical contamination of the air is without effect on the discomfort of men, and the only factors influencing discomfort were moisture and the temperature of the surrounding air.

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[a] Loc. cit., p. 405.

In connection with this consideration of reduced or diminished ventilation, we were able to consult with a number of manufacturers of diving apparatus and submarine appliances, and with the users of such apparatus. It is a common custom for divers to measure the amount of air furnished them by the pressure of certain gauges connected with the pumps. The release valve in the diving helmet is adjusted by the diver himself so as to allow the air to escape as fast as desired. The man at the surface working the pump is supposed to keep the pressure constant. While much of the information regarding the ventilation of diving helmets is based on empirical rather than strict scientific grounds, certain estimations can be made which are probably approximately correct. The manufacturer of one diving apparatus stated that for a diver working at 50 feet under water, sufficient air would be furnished by a 3-cylinder, single-action pump with cylinder of 3.5 inches diameter and a stroke of 6 inches working at about twenty strokes per minute. The volume of air thus delivered, assuming the diver to be at atmospheric pressure, is computed to be 57.1 liters.

Another manufacturer states that a single-cylinder, double-acting pump with a 4-inch cylinder and a 6-inch stroke will supply most men at 50 feet of water. Some men have used it for 60 feet, while others say it is not enough for 40 feet, the same speed being used in all cases. This difference in the amount of air required by different individuals is quite commonly noted by divers. A fair estimation of the average efficiency is said by the second manufacturer to be the amount of air discharged by a 3-cylinder, single-action pump, with pistons 3.25 inches in diameter and a 6-inch stroke. This pump, when supplying a diver at almost any depth, is operated at about thirty turns per minute, thus giving 73.6 liters per minute. It is stated that the English divers use for excessively deep work, say 150 feet, a 3-cylinder, single-action pump, each cylinder 4 inches inside diameter and 6-inch stroke, with about the same number of turns per minute, i. e., 30, which would give a current of 111 liters per minute. Although there are wide variations in the volume of air delivered by these different forms of pump, it is probably fair to assume that divers in general obtain about 65 to 70 liters per minute, or somewhat less than the rate of ventilation in the respiration calorimeter It is stated that divers working in 10 or 20 feet of water could probably work under these conditions for twenty-four hours without coming up, although their sojourn is customarily not longer than five or six hours. The return to the surface, however, when working in shallow water is determined not by any discomfort due to poor ventilation, but simply by the desire for food.

Many remarkable statements have been made regarding the ventilation of the submarine boats, which have made such marked advances in the past decade. We are indebted to Mr. L. Y. Spear, of Quincy, Mass., for the following information regarding the ventilation of the submarine torpedo boat built by the company of which he is vice-president.

In one test one of the boats was submerged for a period of fifteen hours with a crew of six men. The free-air capacity in the interior at about atmospheric pressure was approximately 2,250 cubic feet. No fresh air was supplied nor was any foul air removed, nor any chemical means of purification used. At the expiration of the test the interior of the boat was somewhat "close," like a "stuffy" room, but there were absolutely no observable bad effects upon the members of the crew. The amount of air supplied each man per minute, according to computations based upon these figures, was about 12 liters.

On another occasion, during an official trial at Newport, in June, 1904, the boat was submerged for over twelve hours with nine men on board. No change whatever was made in the air until the expiration of eleven and one-half hours, when the air was renewed by pumping out the foul air and admitting fresh air from compressed stores. This was done merely to demonstrate to the trial board that the apparatus on board for the purpose was satisfactory, and not because there was any discomfort due to the condition of the air. Neither of these tests was carried to its ultimate conclusion, so that we do not know at present just how long a crew could remain without any change in the air supply. Compressed air at 2,500 pounds per square inch, however, is required for other purposes in the boats, and a sufficient excess of this is carried to change the air in the boat several times.

Obviously, in the case of a submarine boat as well as with the divers, the question of temperature of the water would not have to be considered, as this never could rise to a point producing discomfort. Furthermore, the temperature of the water would in most instances be so low that it would be below the dew-point of the air surrounding the body of the subject, and consequently there would be a condensation of moisture on the walls, thus keeping the relative moisture in the helmet or in the submarine boat at a low point.

While these figures are, to be sure, obtained from experiments of only short duration, at the same time they are distinctly significant as supporting the conclusion which has been drawn from the results of the experiments with the respiration calorimeter reported herewith, namely, that the chief factors producing discomfort in so-called poorly ventilated rooms are not the chemical impurities in the air, but the temperature and moisture conditions which affect the heat elimination of the body. Experiments on animals made by Billings, Mitchell, and Bergey[a] with artificial atmospheres, the observations on man by Speck,[b] and those of more recent date by Durig,[c] in breathing artificial atmosphere containing large quantites of carbon dioxid, although experiments of but short duration, show conclusively that no marked disturbances of the respiratory exchange are noted until the percentage of oxygen in the expired air falls as low as 12 per cent. Even in the peculiar conditions and long experiments of the respiration chamber, the nearest approach to this percentage is that of the period ending at 10 a. m. of April 20, experiment No. 63, in which the amount of oxygen fell to 15.3 per cent.

SPECIAL EXPERIMENT ON THE EFFECT OF AN INCREASED AMOUNT OF CARBON DIOXID ON THE RESPIRATORY EXCHANGE AND HEAT PRODUCTION.

Previous investigations upon the effect of breathing air "highly vitiated" by carbon dioxid have been restricted to observations of the respiratory exchange for short periods. The respiration calorimeter in its present form supplements such determinations by measurements of the water eliminated from the lungs and skin and of the heat output. Its use is also especially advantageous in that while data may be obtained for periods as short as two hours, the investigations may be continued several days if desired. Moreover, while subjective symptoms were of great importance in experiments conducted according to the earlier method, in the test here reported they are of interest only as subsidiary evidence.

Experiment No. 60, as has been previously stated, was specifically designed to study the effect of an increased amount of carbon dioxid and a corresponding diminution of oxygen upon the respiratory exchange, heat output, and bodily comfort. The experiment was made with a college student, B. F. D., who had been the subject of numerous short calorimeter experiments of a general nature, although this was his first experience in a long experiment.

For purposes of comparison, it was highly desirable that for at least one day the subject should breathe air as nearly normal as possible.

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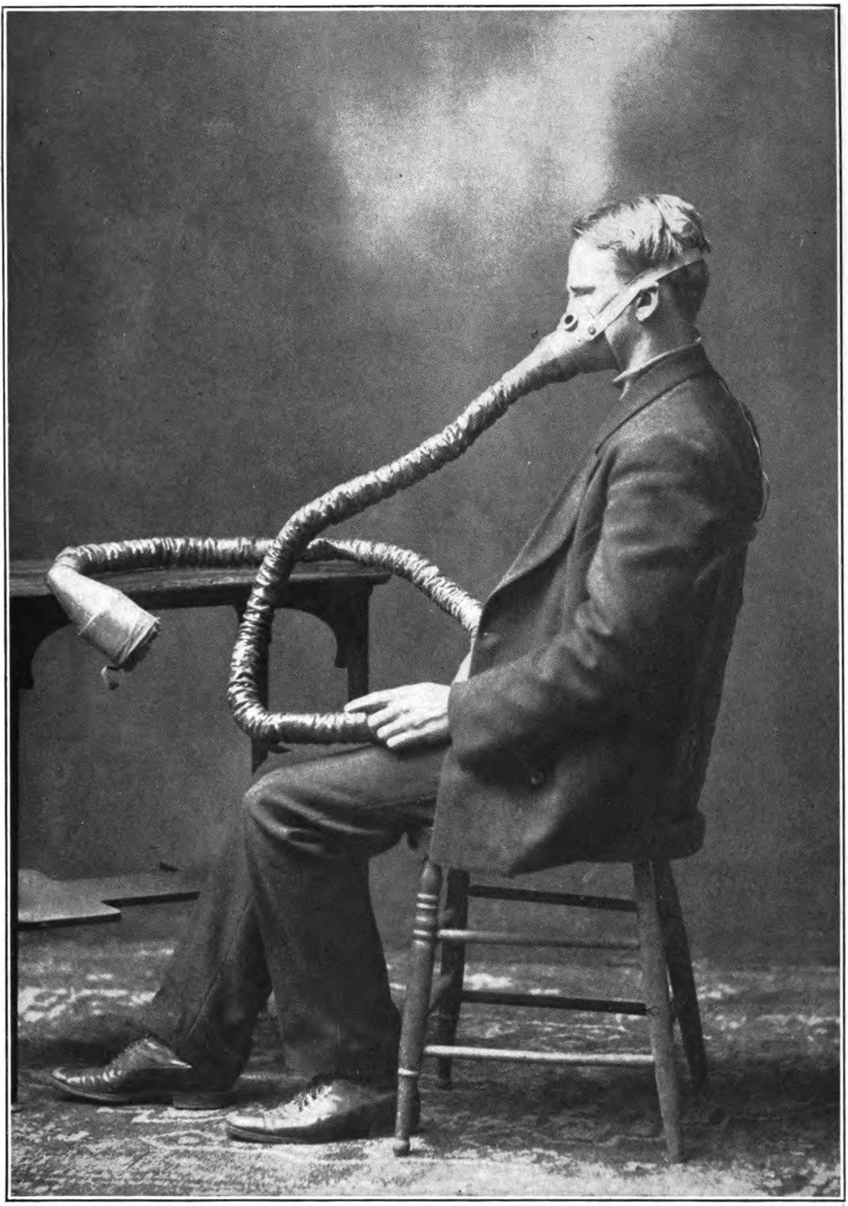
[a] Loc. cit.

[b] Physiologie des menschlichen Athmens. Leipsic, 1895, p. 128.

[c] Arch. Anat. u. Physiol., Physiol. Abt., Suppl., p. 209.



DEVICE FOR THE REMOVAL OF THE RESPIRATORY PRODUCTS FROM THE RESPIRATION CHAMBER (SIDE VIEW).

As has been explained, the ordinary rate of ventilation of the system is so low that carbon dioxid and water vapor inevitably accumulate in the chamber. Furthermore, to effect a complete withdrawal of these products by increased ventilation would necessitate a rate so rapid that the present absorbing system could not be used. It was considered possible, however, to remove the respiratory products from the chamber in another way, by means of a tube leading from immediately in front of the subject's face to the outgoing air pipe. Accordingly a light tube, reinforced on the inside with a light spiral spring and provided with a rubber mask, was attached to the man's face in such a manner as to permit of his inhaling air of the chamber, which in this case remained pure because the products of respiration from both the nose and the mouth were immediately carried out of the chamber through the tube, the other end of which was attached directly to the outgoing air pipe. The mask was of the type commonly used in laboratories to prevent inhalation of dust, the sponge used for this purpose being removed. The tube was about 8 feet long and extremely light. Provision was made to render it of the least possible inconvenience to the subject, by counterpoising it at several points by weights suspended from the ceiling, and he found no difficulty in keeping it in place even during sleep. A view of a subject with the tube and mask attached are shown in Plate II.

Under ordinary circumstances the samples of air for residual analyses are taken from the outgoing air pipe, inasmuch as we assume that the composition of the air in this pipe represents that of the air in the chamber. While this assumption may not be absolutely correct,[a] at least the fluctuations in composition of this air are parallel to the fluctuations in the air in the chamber. In this particular experiment, however, this method was distinctly impracticable. The air in the outgoing air current obviously contained a maximum percentage of carbon dioxid and water vapor, and the large volume of air in the chamber was practically uncontaminated by the products of respiration. Accordingly, a sample of air was drawn through a small opening in the food aperture without in any way contaminating the sample with the products of respiration in the outgoing air pipe.

An inspection of the analyses which are given in Table 104 (p. 246) shows that during the whole day of January 27–28, and especially during the preliminary night, the total amount of carbon dioxid in the chamber was extremely low; the analyses at 1 a. m., 4 a. m., and 7 a. m. showed only about 2 parts per 10,000. The maximum during the day was at 7 p. m., when it reached 17 parts per 10,000. During the night it was difficult to lower this amount materially, but none the less it decreased to 3.74 liters at 4 a. m., corresponding to 8 parts per 10,000, and rose again to 4.90 liters at 7 a. m., corresponding to 10 parts per 10,000.

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[a] See discussion of this point, p. 26.

The results of the usual calorimetric and chemical observations for this experiment are given in the appendix tables and on pages 94–103. The carbon dioxid and heat output and the oxygen intake are of especial importance in discussing the phase of the experiment which bears upon ventilation. On this day the subject eliminated 2,213 calories of heat and 770.68 grams of carbon dioxid and consumed 623.41 grams of oxygen.

During the next day of the experiment, January 28–29, the carbon dioxid inside the chamber was purposely allowed to accumulate rapidly, which was accomplished by cutting down the rate of ventilation to a minimum, especially during the first part of the day. Indeed the pumps were started only a sufficient length of time to obtain an average sample of the air inside the chamber and to put the air in circulation. The absolute amount of carbon dioxid was held at about 100 liters during the rest of the twenty-four hours, reaching a maximum at 10 p. m. and at 7 a. m., when there were 113 grams of carbon dioxid in the air of the chamber, which corresponds to 240 parts per 10,000. It is thus seen that during this particular experiment the subject lived for practically the whole twenty-four hours in an atmosphere which at 10 a. m. was 118 parts per 10,000, and during the rest of the twenty-four hours averaged over 220 parts per 10,000, or over seventy times normal.

On this day the subject gave off 2,200 calories of heat and 761.43 grams of carbon dioxid, and consumed 627.27 grams of oxygen. That is, when there was a very high percentage of carbon dioxid and a diminished proportion of oxygen in the air, the respiratory exchange and the heat evolution were practically the same as on the preceding days when the conditions were not far from normal. To be sure, too great stress must not be placed on the close agreement shown in this experiment, because it is assumed that the bodily activity of the subject was the same in both cases. If on the second day there had been a greater bodily activity than on the first, there would have been a greater carbon dioxid and heat output, and vice versa. So far as we were able to judge, however, there were no material differences in the muscular activity on the two days, in spite of the fact that it might reasonably be inferred that the wearing of the mask and tube on the first day would tend to restrict muscular activity to a greater or less extent. It is certain that no differences in the respiratory exchange and heat output are to be noted which at all correspond to the enormous differences in carbon dioxid content.

The maximum reached during this experiment, 240 parts per 10,000, has been closely approximated in other individual experiments, as, for example, in experiment No. 57, May 9, at 10 a. m. and at 4 p. m. In no other experiment, however, have we the conditions for comparing the effect in respiratory exchange and heat production of air with both the high and low carbon dioxid content as in these first two days of experiment No. 60. None the less, in no experiment carried on thus far have any abnormal results appeared which could be in any way attributed to the increased percentage of carbon dioxid in the chamber. All the subjects have enjoyed their usual good health. Indeed, subject B. F. D. was so pleased to be relieved of the mask that he was in unusually good spirits on the second day of the experiment.

Water Vapor in the Respiration Chamber.

The great importance attributed by other writers to the proportion of water vapor in the air renders a discussion of the hygrometric condition of the air in the respiration chamber of peculiar interest.

Water vapor is continually being given off from the lungs and skin of the subject into the air inside the chamber. A considerable part of this is being withdrawn constantly in the ventilating air current. Under certain conditions the amount residual in the chamber tends to accumulate, and there may also be a very considerable condensation of moisture upon the absorbers and water pipes for removing heat. During rest experiments, when the amount of heat given off is not very great, so that the temperature of the water entering the absorbers to remove the heat need not be made unduly low, there is no perceptible condensation of moisture, and consequently practically all the water vapor given off by the subject is removed in the ventilating air current. When, on the other hand, the subject works hard, large quantities of heat are evolved. In order to bring away this heat as fast as formed the ingoing water current must be cooled to as low a temperature as possible. If in this way the heat absorber is cooled below the dew-point of the air in the chamber the moisture of the air will condense on the metal. This water ultimately finds its way into the troughs or pans suspended immediately beneath the absorbing system (see Pl. I, p. 40), and can be collected in bottles at the end of any given period. Experiments have shown that there is a definite relationship existing between the water given off as a result of increased perspiration, the amount of heat given off, and the temperature at which the ingoing water must be sent into the chamber. By means of the rather delicate adjustments described on page 35, the observer outside is now able to regulate the temperature of the ingoing water so that the moisture content of the air is held within reasonable bounds.

At the end of every experimental period a gravimetric determination of the percentage of moisture in the air is made, from which the total amount of water vapor in the air in the chamber is readily ascertained. From these data, the extent to which the air in the chamber has become saturated—that is, its relative humidity, can be computed as explained on page 249. The relative humidity found in the experiments here reported is given in detail in the last column of Table 104.

During the first two experiments, Nos. 56 and 57, which were work experiments, the relative humidity remained not far from 76 to 79 per cent, usually, although not invariably, falling off during the night. During the rest experiment No. 58 the humidity was considerably lower, and gradually diminished throughout the whole experiment, the average of the last day being about 42 per cent. On the first day of experiment No. 60, when the mask and tube were worn, the relative humidity was much lower than in any other experiment, as was to be expected. The lowest proportion was 25.6 per cent at the end of the twenty-four hours. Contrary, possibly, to what might be expected, the relative humidity on the next day, when the ventilation was so markedly cut down, was not abnormally high, the increase in the amount of water being in no wise comparable to the increase in the amount of carbon dioxid. This shows especially the effect of the condensation of moisture on the heat absorbers. Indeed, it is highly probable that with a rest experiment it would be very difficult to get humidity much higher than 70 per cent with the rate of ventilation here used. The work experiments Nos. 62, 63, and 64 show a humidity comparable to that of the work experiments Nos. 56 and 57. During the rest experiments Nos. 65–67, the humidity materially diminished.

It is important to note that the temperature of the respiration chamber remained practically constant at 20° C. during all these experiments, and this temperature was assumed in all the computations for Table 104.

GENERAL CONCLUSIONS REGARDING VENTILATION.

As a result of the evidence obtained with the respiration calorimeter the following deductions seem justified: (1) That an increase in the amount of carbon dioxid present in the air is absolutely without effect on the mental and bodily comfort of the subjects of the experiments. These subjective observations are paralleled by observations on the respiratory exchange and heat output, neither of which factors is in any way affected. (2) The so-called concomitant impurities of the earlier writers were not discovered in this research. The subjects at no time complained of headache or other discomfort. It is conceivable, to be sure, that the impurities from one individual would have no deleterious effect upon the same individual, but might have on another; yet the water condensed from the respired air, which would probably contain large proportions of such impurities if there had been any, when injected into white rats showed no indication whatever of any virulent toxic poison; and (3) we believe that the unusual control of thermometric and hygrometric conditions of this form of respiration calorimeter precludes conditions of temperature and humidity ordinarily present in poorly ventilated rooms.

Although no attempt is here made to discuss ventilation from the standpoint of hygiene, the observations of Smith[a] are of interest. He determined the humidity and temperature of the external air for the winter months in New York and in Denver, Colo., and also for air indoors in New York, and he shows that living rooms heated artificially without moistening the air are excessively dry. As a result of his experiments he found that with a humidity ranging from 50 to 70 per cent a temperature of 72° F. was considered uncomfortably hot, 68° warm, while 65° was comfortable. Smith emphasizes the fact that dependence should not be placed on thermometers alone in heating buildings, but a hygrometer should also be used and some means for moistening the air.

The results of the experiments with the respiration calorimeter must not be considered in anywise as evidence in favor of a decreased rather than an increased ventilation of ordinary living rooms, lecture halls, and public buildings. The great advantage to all in breathing plenty of pure, fresh outdoor air can not be denied by anyone. The germicidal properties of atmospheric air and sunlight are of the utmost importance in conserving our health. If these experiments throw any more light upon the vexed problems of ventilation and emphasize the importance of determinations of moisture rather than of carbon dioxid, they will have been productive of good results. It is certainly erroneous and unscientific to rely upon the determination of carbon dioxid in the air of a room as a measure of its condition for respiration. The quantity would become serious, of course, when large enough to dilute the air to such an extent that the quantity of oxygen present would be insufficient for daily needs; but it can never accumulate to a serious degree in any ordinary room in which proper attention is given to regulation of the moisture content and temperature.

CONSERVATION OF ENERGY IN THE BODY.

In spite of the fact that there are probable errors of physiological experimenting, which on individual days and, indeed, in individual experiments, may produce errors of considerable magnitude, yet nevertheless the average of the large number of experiments results in the compensation of errors to such an extent that the net income when compared with the net outgo on a long series of experiments shows almost identical agreement. This agreement is shown in Table 105, in which not only the results of the experiments here reported are given, but also those of previously reported experiments.

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[a] Amer. Gas Light Jour., 82 (1905), pp. 330, 451, and 490.

TABLE 105.—*Total income and outgo of energy, metabolism experiments Nos. 56–58 and 60–67.*

Subjects and kinds of experiments.	Duration.	Net income.	Net outgo.	Difference in terms of net income.	
Rest experiments.	*Days.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
H. F., experiment No. 58, carbohydrate diet	3	5,678	5,712	+ 34	+0.6
B. F. D., experiment No. 60, carbohydrate diet	3	6,441	6,683	+242	+3.7
A. L. L., experiment No. 65, carbohydrate diet	1	2,541	2,453	− 88	−3.5
A. L. L., experiment No. 66, carbohydrate diet	1	2,462	2,471	+ 9	+ .4
A. L. L., experiment No. 67, carbohydrate diet	2	5,455	5,377	− 78	−1.4
Total, 3 rest experiments with A. L. L	4	10,458	10,301	−157	−1.5
Total, 5 rest experiments here reported	10	22,577	22,696	+119	+ .5
Total, 22 rest experiments as previously reported	67	151,638	152,051	+413	+ .3
Total, all rest experiments	77	174,215	174,747	+532	+ .3
Work experiments.					
J. C. W., experiment No. 56, fat diet	3	15,423	15,852	+429	+2.7
J. C. W., experiment No. 57, carbohydrate diet	3	16,378	16,304	− 74	− .5
B. F. D., experiment No. 61, carbohydrate diet	1	4,463	4,565	+102	+2.2
A. L. L., experiment No. 62, carbohydrate diet	3	14,257	14,464	+207	+1.5
A. L. L., experiment No. 63, fat diet	3	14,792	14,671	−121	− .8
Total, 5 work experiments	13	65,313	65,856	+543	+ .8
A. L. L., experiment No. 64, severe work, fat diet	1	7,185	7,137	− 48	− .7
Total, 6 work experiments here reported	14	72,498	72,993	+495	+ .7
Total, 23 work experiments as previously reported	76	346,167	345,641	−526	− .2
Total, all work experiments	90	418,665	418,634	− 31	....
Total, all rest and work experiments here reported	24	95,075	95,689	+614	+ .6
Total, all rest and work experiments	167	592,880	593,381	+501	+ .1

Taking the rest experiments into consideration, it is seen that in the five rest experiments here reported there were 22,577 calories in the net income and 22,696 calories in the net outgo, an increase of 119 calories, or 0.5 per cent. In the twenty-two rest experiments previously reported there was a net income of 151,638 calories and a net outgo of 152,051 calories, an increase of 413 calories, or 0.3 per cent. In all the rest experiments thus far reported, covering seventy-seven days, the net income is 174,215 calories and the net outgo 174,747 calories, the net outgo being greater by 532 calories, or 0.3 per cent. In the work experiments the quantities involved are much larger, and in the six work experiments here reported, covering fourteen days, there were 72,498 calories in the income and 72,993 calories in the outgo, which was greater by 495 calories than the income, an error of +0.7 per cent. Taking into consideration all the work experiments previously reported and those here reported, covering in all ninety days, the total income was 418,665 calories and the total outgo 418,634 calories, the difference being −31 calories. In the twenty-four days of rest and work experiments here reported there is a difference of 614 calories in about 95,000, an error of +0.6 per cent. With all the experiments thus far made with the respiration calorimeter, covering one hundred and sixty-seven days, the net income is 592,880 calories and the net outgo 593,381 calories, the outgo being greater by 501 calories than the income. The error is therefore but 0.1 per cent.

It is perhaps significant that with both the rest and work experiments the amounts measured by the calorimeter are slightly greater than those assumed as oxidized in the body. From the results of many alcohol and electrical check experiments it seems highly probable that the amounts measured by the calorimeter are correct, and the error is probably due to the use of certain factors in computing the potential energy of the material oxidized in the body, as explained in the preceding sections (p. 75).

While there is no attempt to minimize the fact that the close agreement in the above results is largely due to compensating errors, it still seems reasonable to conclude, from the smallness of the variations in the several experiments, that there can be no material quantities of energy that leave the body other than those measured by the calorimeter. The results of these measurements may therefore be taken as signifying that the law of the conservation of energy obtains in the human body.

APPENDIX.

The fundamental data of the metabolism experiments are very numerous. Inasmuch as they are an essential part of the record of the experiments, they are included in the report, but in order that the account of the investigations may be the more concise these details are given as an appendix. Even here the data in some cases have been condensed from the actual records during the investigations, but nothing essential has been omitted.

TABLE 106.—*Amount, specific gravity, and nitrogen of urine by periods, metabolism experiments Nos. 56–58 and 60–67.*

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
	Preliminary to experiment No. 56.				
1903.		*Grams.*		*Per cent.*	*Grams.*
Apr. 23–24	7 a. m. to 7 a. m	1,457.2	1.0275	1.060	15.45
Apr. 24–25	7 a. m. to 7 a. m	667.3	1.0375	1.950	13.01
Apr. 25–26	7 a. m. to 1 p. m	215.8	1.0350	1.620	3.50
	1 p. m. to 7 p. m	256.6	1.0345	1.600	4.11
	7 p. m. to 11 p. m	91.0	1.0385	2.120	1.93
	11 p. m. to 7 a. m	369.9	1.0270	1.460	5.40
	Total	933.3			14.94
	Total by composite	933.3	1.0315	1.590	14.84
Apr. 26–27	7 a. m. to 1 p. m	240.3	1.0235	1.396	3.35
	1 p. m. to 7 p. m	542.8	1.0170	.755	4.10
	7 p. m. to 11 p. m	492.3	1.0140	.575	2.83
	11 p. m. to 7 a. m	351.4	1.0220	1.026	3.61
	Total	1,626.8			13.89
	Total by composite	1,626.8	1.0190	.857	13.94
	Experiment No. 56.				
Apr. 27–28	7 a. m. to 1 p. m	374.2	1.0225	.891	3.33
	1 p. m. to 7 p. m	593.2	1.0190	.644	3.82
	7 p. m. to 11 p. m	178.2	1.0265	1.540	2.74
	11 p. m. to 7 a. m	350.0	1.0240	1.263	4.42
	Total	1,495.6			14.31
	Total by composite	1,495.6	1.0230	.954	14.27
Apr. 28–29	7 a. m. to 1 p. m	317.0	1.0190	1.085	3.44
	1 p. m. to 7 p. m	284.5	1.0300	1.462	4.16
	7 p. m. to 11 p. m	136.8	1.0330	2.127	2.91
	11 p. m. to 7 a. m	234.7	1.0320	2.122	4.98
	Total	973.0			15.49
	Total by composite	973.0	1.0290	1.586	15.43
Apr. 29–30	7 a. m. to 1 p. m	206.0	1.0300	2.093	4.31
	1 p. m. to 7 p. m	348.2	1.0250	1.679	5.85
	7 p. m. to 11 p. m	141.3	1.0350	1.324	1.87
	11 p. m. to 7 a. m	263.6	1.0290	1.987	5.14
	Total	959.1			17.17
	Total by composite	959.1	1.0280	1.810	17.36
	Total, 3 days	3,427.7			46.97
	Total, 3 days, by composite	3,427.7	1.0250	1.382	47.37

Table 106.—*Amount, specific gravity, and nitrogen of urine by periods, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
1903.	*Preliminary to experiment No. 57.*	*Grams.*		*Per cent.*	*Grams.*
May 3–4		2,073.8	1.0190	0.807	16.74
May 4–5	7 a. m. to 7 a. m	791.3	1.0320	1.560	12.34
May 5–6	7 a. m. to 1 p. m	136.5	1.0320	1.810	2.47
	1 p. m. to 7 p. m	167.5	1.0380	1.835	3.07
	7 p. m. to 11 p. m	122.5	1.0390	2.200	2.70
	11 p. m. to 7 a. m	504.5	1.0180	.857	4.32
	Total	931.0			12.56
	Total by composite	931.0	1.0250	1.350	12.57
May 6–7	7 a. m. to 1 p. m	185.0	1.0340	1.506	2.79
	1 p. m. to 7 p. m	198.5	1.0370	1.660	3.30
	7 p. m. to 11 p. m	165.5	1.0385	1.635	2.71
	11 p. m. to 7 a. m	450.3	1.0215	.845	3.81
	Total	999.3			12.61
	Total by composite	999.3	1.0290	1.257	12.56
	Experiment No. 57.				
May 7–8	7 a. m. to 1 p. m	329.4	1.0300	1.032	3.40
	1 p. m. to 7 p. m	281.0	1.0360	1.238	3.48
	7 p. m. to 11 p. m	132.6	1.0410	1.779	2.36
	11 p. m to 7 a. m	246.5	1.0310	1.611	3.97
	Total	989.5			13.21
	Total by composite	989.5	1.0330	1.330	13.16
May 8–9	7 a. m. to 1 p. m	197.7	1.0380	1.800	3.56
	1 p. m. to 7 p. m	273.1	1.0380	1.547	4.22
	7 p. m. to 11 p. m	130.5	1.0440	2.146	2.80
	11 p. m. to 7 a. m	236.3	1.0340	1.865	4.41
	Total	837.6			14.99
	Total by composite	837.6	1.0350	1.784	14.94
May 9–10	7 a. m. to 1 p. m	239.7	1.0390	1.626	3.90
	1 p. m. to 7 p. m	230.9	1.0390	1.813	4.19
	7 p. m. to 11 p. m	145.4	1.0400	2.204	3.20
	11 p. m. to 7 a. m	240.1	1.0310	1.879	4.51
	Total	856.1			15.80
	Total by composite	856.1	1.0360	1.833	15.69
	Total, 3 days	2,683.2			44.00
	Total, 3 days, by composite	2,683.2	1.0410	1.625	43.60
	Preliminary to experiment No. 58.				
Nov. 7–8	7 a. m. to 7 a. m	354.3	1.0315	1.540	5.47
Nov. 8–9	7 a. m. to 7 a. m	387.4	1.0330	1.730	6.69
Nov. 9–10	7 a. m. to 7 a. m	233.0	1.0330	2.010	4.67
	Experiment No. 58.				
Nov. 10–11	7 a. m. to 7 a. m	403.8	1.0310	1.930	7.79
Nov. 11–12	7 a. m. to 7 a. m	399.7	1.0325	2.070	8.27
Nov. 12–13	7 a. m. to 7 a. m	447.0	1.0330	2.090	9.34
	Total, 3 days	1,250.5			25.40
	Total, 3 days, by composite	1,250.5	1.0340	1.998	24.98
	Preliminary to experiment No. 60.				
1904.					
Jan. 21–22	7 a. m. to 7 a. m	876.6	1.0340	1.670	14.70
Jan. 22–23	7 a. m. to 7 a. m	801.0	1.0345	1.900	15.23
Jan. 23–24	7 a. m. to 7 a. m	886.7	1.0325	1.810	16.04
Jan. 24–25	7 a. m. to 7 a. m	882.8	1.0340	1.700	14.97

TABLE 106.—*Amount, specific gravity, and nitrogen of urine by periods, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
	Preliminary to experiment No. 60—Continued.				
1904.		*Grams.*		*Per cent.*	*Grams.*
Jan. 25–26	7 a. m. to 1 p. m	243.4	1.0295	1.420	3.45
	1 p. m. to 7 p. m	183.0	1.0320	1.530	2.80
	7 p. m. to 11 p. m	273.2	1.0345	1.570	4.30
	11 p. m. to 7 a. m	240.2	1.0335	1.720	4.14
	Total	939.8			14.69
	Total by composite	939.8	1.0310	1.570	14.72
Jan. 26–27	7 a. m. to 1 p. m	378.0	1.0290	1.450	5.49
	1 p. m. to 7 p. m	201.3	1.0330	1.490	3.00
	7 p. m. to 11 p. m	114.6	1.0340	1.660	1.91
	11 p. m. to 7 a. m	245.0	1.0330	1.860	4.55
	Total	938.9			14.95
	Total by composite	938.9	1.0325	1.590	14.94
	Total, 2 days	1,878.7			29.64
	Total, 2 days, by composite	1,878.7		1.690	31.75
	Experiment No. 60.				
Jan. 27–28	7 a. m. to 1 p. m	245.8	1.0345	1.440	3.54
	1 p. m. to 7 p. m	316.0	1.0345	1.470	4.65
	7 p. m. to 11 p. m	180.8	1.0365	1.590	2.88
	11 p. m. to 7 a. m	365.2	1.0300	1.470	5.38
	Total	1,107.8			16.45
	Total by composite	1,107.8	1.0335	1.490	16.48
Jan. 28–29	7 a. m. to 1 p. m	224.0	1.0300	1.620	3.63
	1 p. m. to 7 p. m	271.6	1.0340	1.560	4.25
	7 p. m. to 11 p. m	182.7	1.0350	1.640	2.99
	11 p. m. to 7 a. m	328.9	1.0215	1.180	3.87
	Total	1,007.2			14.74
	Total by composite	1,007.2	1.0290	1.450	14.64
Jan. 29–30	7 a. m. to 1 p. m	287.5	1.0280	1.300	3.75
	1 p. m. to 7 p. m	260.0	1.0330	1.590	4.12
	7 p. m. to 11 p. m	190.9	1.0330	1.560	2.98
	11 p m. to 7 a. m	636.8	1.0190	.800	5.10
	Total	1,375.2			15.95
	Total by composite	1,375.2	1.0250	1.160	15.89
	Total, 3 days	3,490.2			47.14
	Total, 3 days, by composite	3,490.2	1.0310	1.330	46.43
	Experiment No. 61.				
Jan. 30–31	7 a. m. to 1 p. m	200.7	1.0270	1.340	2.69
	1 p. m. to 7 p. m	274.0	1.0340	1.600	4.38
	7 p. m. to 11 p. m	175.8	1.0355	2.050	3.60
	11 p. m. to 7 a. m	254.5	1.0345	2.280	5.79
	Total	905.0			16.46
	Total by composite	905.0	1.0310	1.820	16.51
	Following experiment No. 61.				
Jan. 31–Feb. 1	7 a. m. to 7 a. m	733.4	1.0350	2.000	14.65
	Preliminary to experiment No. 62.				
Apr. 12–13	7 a. m. to 7 a. m	648.3	1.0385	2.339	15.16
Apr. 13–14	7 a. m. to 7 a. m	714.6	1.0365	2.291	16.37
Apr. 14–15	7 a. m. to 7 a. m	756.8	1.0360	2.001	15.14
Apr. 15–16	7 a. m. to 7 a. m	669.6	1.0395	2.150	14.40
	Total, 4 days	2,789.3			61.07
	Total, 4 days, by composite	2,789.3	1.0365	2.185	60.95

TABLE 106.—*Amount, specific gravity, and nitrogen of urine by periods, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
	Experiment No. 62.				
1904.		*Grams.*		*Per cent.*	*Grams.*
Apr. 16–17	7 a. m. to 10 a. m	55.8	1.0360	2.829	1.58
	10 a. m. to 7 p. m	221.7	1.0405	2.472	5.48
	7 p. m. to 11 p. m	95.2	1.0465	2.830	2.69
	11 p. m. to 7 a. m	167.5	1.0410	2.876	4.82
	Total	540.2			14.57
	Total by composite	540.2	1.0420	2.682	14.49
Apr. 17–18	7 a. m. to 1 p. m	131.7	1.0385	2.734	3.60
	1 p. m. to 7 p. m	150.4	1.0410	2.411	3.63
	7 p. m. to 11 p. m	101.3	1.0420	2.825	2.86
	11 p. m. to 7 a. m	161.0	1.0405	3.058	4.92
	Total	544.4			15.01
	Total by composite	544.4	1.0405	2.768	15.07
Apr. 18–19	7 a. m. to 1 p. m	150.4	1.0360	2.673	4.02
	1 p. m. to 7 p. m	198.9	1.0390	2.161	4.30
	7 p. m. to 11 p. m	142.9	1.0385	2.399	3.43
	11 p. m. to 7 a. m	198.0	1.0380	2.527	5.00
	Total	690.2			16.75
	Total by composite	690.2	1.0395	2.436	16.81
	Total, 3 days	1,774.8			46.33
	Total, 3 days, by composite	1,774.8	1.0395	2.588	45.93
	Experiment No. 63.				
Apr. 19–20	7 a. m. to 1 p. m	149.0	1.0345	2.194	3.27
	1 p. m. to 7 p. m	252.7	1.0330	1.602	4.05
	7 p. m. to 11 p. m	243.5	1.0295	1.491	3.63
	11 p. m. to 7 a. m	313.3	1.0230	1.045	3.27
	Total	958.5			14.22
	Total by composite	958.5	1.0270	1.503	14.41
Apr. 20–21	7 a. m. to 1 p. m	456.2	1.0250	1.113	5.08
	1 p. m. to 7 p. m	373.9	1.0260	1.010	3.78
	7 p. m. to 11 p. m	452.5	1.0250	1.080	4.89
	11 p. m. to 7 a. m	563.0	1.0220	.999	5.62
	Total	1,845.6			19.37
	Total, by composite	1,845.6	1.0240	1.046	19.31
Apr. 21–22	7 a. m. to 1 p. m	423.5	1.0220	.997	4.22
	1 p. m. to 7 p. m	458.3	1.0250	1.034	4.74
	7 p. m. to 11 p. m	340.5	1.0245	1.187	4.04
	11 p. m. to 7 a. m	621.4	1.0230	1.103	6.85
	Total	1,843.7			19.85
	Total, by composite	1,843.7	1.0235	1.067	19.67
	Total, 3 days	4,647.8			53.44
	Total, 3 days, by composite	4,647.8	1.0240	1.146	53.26
	Experiment No. 64.				
Apr. 22–23	7 a. m. to 1 p. m	192.2	1.0260	1.290	2.48
	1 p. m. to 7 p. m	299.3	1.0265	1.073	3.21
	7 p. m. to 11 p. m	155.4	1.0300	1.208	1.88
	11 p. m. to 7 a. m	489.2	1.0290	1.657	8.11
	Total	1,136.1			15.68
	Total, by composite	1,136.1	1.0285	1.371	15.58

Table 106.—*Amount, specific gravity, and nitrogen of urine by periods, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Amount.	Specific gravity.	Nitrogen.	
	Experiment No. 65.				
1904.		*Grams.*		*Per cent.*	*Grams.*
Apr. 23–24	7 a. m. to 1 p. m.	284.9	1.0295	2.222	6.33
	1 p. m. to 7 p. m.	287.0	1.0305	2.258	6.48
	7 p. m. to 11 p. m.	195.2	1.0305	2.301	4.49
	11 p. m. to 7 a. m.	316.5	1.0285	2.123	6.72
	Total	1,083.6			24.02
	Total, by composite	1,083.6	1.0290	2.219	24.05
	Experiment No. 66.				
Apr. 24–25	7 a. m. to 1 p. m.	136.6	1.0305	2.245	3.07
	1 p. m. to 7 p. m.	380.0	1.0315	2.316	8.80
	7 p. m. to 11 p. m.	148.5	1.0345	2.502	3.71
	11 p. m. to 7 a. m.	376.6	1.0235	1.787	6.73
	Total	1,041.7			22.31
	Total, by composite	1,041.7	1.0290	2.124	22.13
	Experiment No. 67.				
Apr. 25–26	7 a. m. to 1 p. m.	202.6	1.0290	2.138	4.33
	1 p. m. to 7 p. m.	223.4	1.0315	2.282	5.10
	7 p. m. to 11 p. m.	235.5	1.0225	1.402	3.30
	11 p. m. to 7 a. m.	414.8	1.0230	1.379	5.72
	Total	1,076.3			18.45
	Total, by composite	1,076.3	1.0270	1.718	18.49
Apr. 26–27	7 a. m. to 1 p. m.	255.3	1.0265	1.475	3.77
	1 p. m. to 7 p. m.	360.4	1.0240	1.308	4.71
	7 p. m. to 11 p. m.	196.5	1.0270	1.522	2.99
	11 p. m. to 7 a. m.	532.2	1.0195	.930	4.95
	Total	1,344.4			16.42
	Total, by composite	1,344.4	1.0235	1.208	16.24
	Total, 4 days, experiments Nos. 65–67	4,546.0			81.20
	Total, 4 days, experiments Nos. 65–67, by composite	4,546.0	1.0265	1.766	80.28
	Following experiment No. 67.				
Apr. 27–28	7 a. m. to 1 p. m.	267.5	1.0190	1.081	2.89
	1 p. m. to 7 p. m.	264.6	1.0220	1.252	3.31
	7 p. m. to 11 p. m.	172.1	1.0215	1.211	2.08
	11 p. m. to 7 a. m.	297.5	1.0230	1.336	3.98
	Total	1,001.7			12.26
	Total, by composite	1,001.7	1.0230	1.230	12.32
Apr. 28–29	7 a. m. to 1 p. m.	221.9	1.0225	1.390	3.08
	1 p. m. to 7 p. m.	223.1	1.0260	1.553	3.47
	7 p. m. to 7 a. m.	398.8	1.0270	1.624	6.48
	Total	843.8			13.03
	Total, by composite	843.8	1.0265	1.547	13.05
	Total, 2 days	1,845.5			25.29
	Total, 2 days, by composite	1,845.5	1.0255	1.357	25.04
Apr. 29–30	7 a. m. to 7 a. m.	961.3	1.0255	1.763	16.95

TABLE 107.—*Percentage composition and heat of combustion of urine, metabolism experiments Nos. 56–58 and 60–67.*

Experiment No.	Date.	Water.	Total solids.	Nitrogen.	Carbon.	Hydrogen.	Ash.	Heat of combustion per gram.
	1903.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
[a] P56	Apr. 23–24			1.06				
P56	24–25			1.95				
P56	25–27			1.12				0.100
56	27–28			.95				.098
56	28–29			1.59				.134
56	29–30			1.81				.144
56	3-day composite	95.33	4.67	1.38	1.11	0.28	0.94	.121
P57	May 3– 4			.81				
P57	4– 5			1.56				
P57	5– 6			1.35				.126
P57	6– 7			1.26				.128
57	7– 8			1.33				.122
57	8– 9			1.78				.152
57	9–10			1.83				.158
57	3-day composite	94.21	5.79	1.63	1.33	.35	1.28	.153
P58				1.54				.164
P58				1.73				.170
P58				2.01				.200
58				1.93				.178
58				2.07				.185
58				2.09				.182
	6-day composite	91.95	8.05	2.00	1.79	.44	1.44	.195
	1904.							
P60	Jan. 21–22			1.67				
P60	22–23			1.90				
P60	23–24			1.81				
P60	24–25			1.70				
P60	25–26			1.57				
P60	26–27			1.59				
P60	6-day composite			1.69				.150
60	Jan. 27–28			1.49				.123
60	28–29			1.45				.117
60	29–30			1.16				.098
60	3-day composite	94.45	5.55	1.33	1.20	.28	1.46	
61	Jan. 30–31	93.15	6.85	1.82	1.42	.37	1.61	.153
P62	Apr. 12–13			2.34				
P62	13–14			2.29				
P62	14–15			2.00				
P62	15–16			2.15				
P62	4-day composite			2.19				.181
62	Apr. 16–17			2.68				.234
62	17–18			2.77				.237
62	18–19			2.44				.200
62	3-day composite	90.80	9.20	2.59	2.12	.50	1.28	.227
63	Apr. 19–20			1.50				.118
63	20–21			1.05				.080
63	21–22			1.07				.080
63	3-day composite	95.30	4.70	1.15	.87	.23	1.30	.092
64	Apr. 22–23	94.67	5.33	1.37	1.03	.29	1.12	.113
65	23–24			2.22				.162
66	24–25			2.12				.151
67	25–26			1.72				.128
	26–27			1.21				.091
65–67	4-day composite	94.19	5.81	1.77	1.19	.31	.94	.136

[a] The letter P indicates the period preliminary to that of the experiment proper.

Table 108.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period and the corresponding gain or loss, metabolism experiments Nos. 56–58 and 62–67.*

Date.	End of period.	Carbon dioxid.		Water.				
		Total amount in chamber.	Gain (+) or loss (−) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (−) over preceding period.	Change in weight of absorbers. Gain (+) or loss (−).	Amount absorbed by underclothes.	Total amount gained (+) or lost (−) during the period.
	Preliminary to experiment No. 56.							
1903.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 27.....	1 a. m..................	37.25	....	56.84	....	....	....	....
	1 a. m. to 7 a. m.....	42.55	+ 5.30	54.64	− 2.20	....	....	− 2.20
	Experiment No. 56.							
Apr. 27–28..	7 a. m. to 1 p. m.....	142.38	+ 99.83	67.95	+13.31	+1,003.82	55.10	+1,072 23
	1 p. m. to 7 p. m.....	117.28	− 25.10	68.82	+ .87	+1,190.02	55.00	+1,245.89
	7 p. m. to 1 a. m.....	48.38	− 68.90	64.04	− 4.78	+ 75.30	....	+ 70.52
	1 a. m. to 7 a. m.....	40.53	− 7.85	63.14	− .90	+ 74.46	....	+ 73.56
	Total..........	....	− 2.02	....	+ 8.50	+2,343.60	110.10	+2,462.20
Apr. 28–29..	7 a. m. to 10 a. m....	169.09	+128.56	66.02	+ 2.88	+ 679.41	39.70	+ 721.99
	10 a. m. to 1 p. m....	151.04	− 18.05	69.96	+ 3.94	+ 679.41	39.80	+ 723.15
	1 p. m. to 4 p. m.....	170.73	+ 19.69	68.22	− 1.74	+ 621.91	39.70	+ 659.87
	4 p. m. to 7 p. m.....	91.04	− 79.69	64.97	− 3.25	+ 621.91	39.70	+ 658.36
	7 p. m. to 10 p. m....	53.18	− 37.86	66.47	+ 1.50	+ 16.39	....	+ 17.89
	10 p. m. to 1 a. m....	41.87	− 11.31	68.60	+ 2.13	+ 16.39	....	+ 18.52
	1 a. m. to 4 a. m.....	33.61	− 8.26	68.71	+ .11	+ 15.89	....	+ 16.00
	4 a. m. to 7 a. m.....	38.15	+ 4.54	63.70	− 5.01	+ 15.89	....	+ 10.88
	Total..........	....	− 2.38	....	+ .56	+2,667.20	158.90	+2,826.66
Apr. 29–30..	7 a. m. to 10 a. m....	158.16	+120.01	65.21	+ 1.51	+ 533.62	51.00	+ 586.13
	10 a. m. to 1 p. m....	85.23	− 72.93	66.30	+ 1.09	+ 533.62	51.00	+ 585.71
	1 p. m. to 4 p. m.....	171.02	+ 85.79	67.43	+ 1.13	+ 638.33	51.00	+ 690.46
	4 p. m. to 7 p. m.....	105.73	− 65.29	66.77	− .66	+ 638.32	50.90	+ 688.56
	7 p. m. to 10 p. m....	56.24	− 49.49	62.62	− 4.15	+ 28.83	....	+ 24.68
	10 p. m. to 1 a. m....	44.96	− 11.28	69.79	+ 7.17	+ 28.83	....	+ 36.00
	1 a. m. to 4 a. m.....	39.90	− 5.06	67.11	− 2.68	+ 28.33	....	+ 25.65
	4 a. m. to 7 a. m.....	35.49	− 4.41	60.37	− 6.74	+ 28.32	....	+ 21.58
	Total..........	....	− 2.66	....	− 3.33	+2,458.20	203.90	+2,658.77
	Total 3 days...	....	− 7.06	....	+ 5.73	+7,469.00	472.90	+7,947.63
	Preliminary to experiment No. 57.							
May 7......	1 a. m..................	42.37	....	60.63	....	....	....	....
	1 a. m. to 4 a. m.....	41.75	− .62	60.09	− .54	....	....	− .54
	4 a. m. to 7 a. m.....	38.95	− 2.80	54.52	− 5.57	....	....	− 5.57
	Total..........	....	− 3.42	....	− 6.11	....	....	− 6.11
	Experiment No. 57.							
May 7–8....	7 a. m. to 10 a. m....	142.22	+103.27	61.42	+ 6.90	+ 650.00	35.50	+ 692.40
	10 a. m. to 1 p. m....	135.80	− 6.42	65.06	+ 3.64	+ 650.00	35.50	+ 689.14
	1 p. m. to 4 p. m.....	158.88	+ 23.08	66.82	+ 1.76	+ 495.20	35.50	+ 532.46
	4 p. m. to 7 p. m.....	114.45	− 44.43	66.99	+ .17	+ 495.20	35.50	+ 530.87
	7 p. m. to 10 p. m....	75.76	− 38.69	65.12	− 1.87	+ 53.00	....	+ 51.13
	10 p. m. to 1 a. m....	86.59	+ 10.83	69.75	+ 4.63	+ 53.00	....	+ 57.63
	1 a. m. to 4 a. m.....	56.42	− 30.17	64.32	− 5.43	+ 42.90	....	+ 37.47
	4 a. m. to 7 a. m.....	50.94	− 5.48	61.27	− 3.05	+ 42.90	....	+ 39.85
	Total..........	....	+ 11.99	....	+ 6.75	+2,482.20	142.00	+2,630.95
May 8–9....	7 a. m. to 10 a. m....	170.44	+119.50	68.06	+ 6.79	+ 590.40	40.10	+ 637.29
	10 a. m. to 1 p. m....	92.79	− 77.65	68.84	+ .78	+ 590.40	40.10	+ 631.28
	1 p. m. to 4 p. m.....	150.35	+ 57.56	65.70	− 3.14	+ 631.50	40.10	+ 668.46
	4 p. m. to 7 p. m.....	107.06	− 43.29	68.64	+ 2.94	+ 631.50	40.00	+ 674.44
	7 p. m. to 10 p. m....	49.77	− 57.29	60.53	− 8.11	+ 19.20	....	+ 11.09
	10 p. m. to 1 a. m....	37.98	− 11.79	65.05	+ 4.52	+ 19.20	....	+ 23.72
	1 a. m. to 4 a. m.....	23.98	− 14.00	58.93	− 6.12	+ 14.10	....	+ 7.98
	4 a. m. to 7 a. m.....	28.15	+ 4.17	58.35	− .58	+ 14.10	....	+ 13.52
	Total..........	....	− 22.79	....	− 2.92	+2,510.40	160.30	+2,667.78

Table 108.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period and the corresponding gain or loss, metabolism experiments Nos. 56–58 and 62–67*—Continued.

Date.	End of period.	Carbon dioxid.		Water.				
		Total amount in chamber.	Gain (+) or loss (−) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (−) over preceding period.	Change in weight of absorbers. Gain (+) or loss (−).	Amount absorbed by underclothes.	Total amount gained (+) or lost (−) during the period.
	Experiment No. 62—Continued.							
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 18–19..	7 a. m. to 10 a. m....	158.77	+126.91	67.03	+16.30	+ 572.40	24.70	+ 613.40
	10 a. m. to 1 p. m....	114.23	− 44.54	63.44	− 3.59	+ 572.40	24.70	+ 593.51
	1 p. m. to 4 p. m.....	151.21	+ 36.98	64.77	+ 1.33	+ 572.40	24.70	+ 598.43
	4 p. m. to 7 p. m.....	92.70	− 58.51	62.14	− 2.63	+ 572.30	24.70	+ 594.37
	7 p. m. to 10 p. m....	65.03	− 27.67	57.23	− 4.91	....	....	− 4.91
	10 p. m. to 1 a. m....	39.63	− 25.40	57.74	+ .51	....	....	+ .51
	1 a. m. to 4 a. m.....	40.76	+ 1.13	58.74	+ 1.00	....	....	+ 1.00
	4 a. m. to 7 a. m.....	34.53	− 6.23	57.29	− 1.45	....	....	− 1.45
	Total..........	....	+ 2.67	....	+ 6.56	+2,289.50	98.80	+2,394.86
	Total, 3 days..	....	+ 5.34	....	+ 8.03	+5,864.10	290.00	+6,162.13
	Experiment No. 63.							
Apr. 19–20..	7 a. m. to 10 a. m....	161.75	+127.22	70.91	+13.62	+ 618.10	38.10	+ 669.12
	10 a. m. to 1 p. m....	94.79	− 66.96	65.88	− 5.03	+ 618.00	38.00	+ 650.97
	1 p. m. to 4 p. m.....	128.09	+ 33.30	63.23	− 2.65	+ 618.00	38.00	+ 653.35
	4 p. m. to 7 p. m.....	66.20	− 61.89	60.38	− 2.85	+ 618.00	38.00	+ 653.15
	7 p. m. to 10 p. m....	46.36	− 19.84	58.16	− 2.22	....	....	− 2.22
	10 p. m. to 1 a. m....	34.89	− 11.47	60.12	+ 1.96	....	....	+ 1.96
	1 a. m. to 4 a. m.....	32.01	− 2.88	58.69	− 1.43	....	....	− 1.43
	4 a. m. to 7 a. m.....	30.17	− 1.84	61.00	+ 2.31	....	....	+ 2.31
	Total..........	....	− 4.36	....	+ 3.71	+2,472.10	152.10	+2,627.91
Apr. 20–21..	7 a. m. to 10 a. m....	148.08	+117.91	71.63	+10.63	+ 495.00	45.70	+ 551.33
	10 a. m. to 1 p. m....	95.15	− 52.93	63.16	− 8.47	+ 495.00	45.70	+ 532.23
	1 p. m. to 4 p. m.....	116.31	+ 21.16	63.24	+ .08	+ 495.00	45.70	+ 540.78
	4 p. m. to 7 p. m.....	71.15	− 45.16	62.14	− 1.10	+ 494.90	45.60	+ 539.40
	7 p. m. to 10 p. m....	44.95	− 26.20	57.57	− 4.57	....	....	− 4.57
	10 p. m. to 1 a. m....	37.92	− 7.03	61.36	+ 3.79	....	....	+ 3.79
	1 a. m. to 4 a. m.....	27.10	− 10.82	55.51	− 5.85	....	....	− 5.85
	4 a. m. to 7 a. m.....	32.94	+ 5.84	62.65	+ 7.14	....	....	+ 7.14
	Total..........	....	+ 2.7	....	+ 1.65	+1,979.90	182.70	+2,164.25
Apr. 21–22..	7 a. m. to 10 a. m....	136.81	+103.87	70.14	+ 7.49	+ 541.90	44.50	+ 593.89
	10 a. m. to 1 p. m....	87.19	− 49.62	65.42	− 4.72	+ 541.90	44.50	+ 581.68
	1 p. m. to 4 p. m.....	120.98	+ 33.79	65.68	+ .26	+ 541.80	44.50	+ 586.56
	4 p. m. to 7 p. m.....	69.44	− 51.54	61.29	− 4.39	+ 541.80	44.50	+ 581.91
	7 p. m. to 10 p. m....	45.29	− 24.15	56.80	− 4.49	....	....	− 4.49
	10 p. m. to 1 a. m...	35.99	− 9.30	61.23	+ 4.43	....	....	+ 4.43
	1 a. m. to 4 a. m.....	38.13	+ 2.14	55.77	− 5.46	....	....	− 5.46
	4 a. m. to 7 a. m.....	30.95	− 7.18	52.44	− 3.33	....	....	− 3.33
	Total..........	....	− 1.99	....	−10.21	+2,167.40	178.00	+2,335.19
	Total, 3 days..	....	− 3.58	....	− 4.85	+6,619.40	512.80	+7,127.35
	Experiment No. 64.							
Apr. 22–23..	7 a. m. to 10 a. m....	157.42	+126.47	70.03	+17.59	+ 622.80	13.20	+ 653.59
	10 a. m. to 1 p. m....	91.95	− 65.47	66.77	− 3.26	+ 622.80	13.20	+ 632.74
	1 p. m. to 4 p. m.....	131.11	+ 39.16	69.55	+ 2.78	+ 622.80	13.20	+ 638.78
	4 p. m. to 7 p. m.....	90.13	− 40.98	63.77	− 5.78	+ 622.80	13.20	+ 630.22
	7 p. m. to 10 p. m....	137.85	+ 47.72	71.49	+ 7.72	+ 622.80	13.20	+ 643.72
	10 p. m. to 1 a. m....	66.63	− 71.22	65.53	− 5.96	+ 622.80	13.10	+ 629.94
	1 a. m. to 4 a. m.....	61.67	− 4.96	61.40	− 4.13	+ 622.80	13.10	+ 631.77
	4 a. m. to 7 a. m.....	33.64	− 28.03	60.39	− 1.01	....	....	− 1.01
	Total..........	....	+ 2.69	....	+ 7.95	+4,359.60	92.20	+4,459.75

Table 108.—*Comparison of residual amounts of carbon dioxid and water in the chamber at the beginning and end of each period and the corresponding gain or loss, metabolism experiments Nos. 56–58 and 62–67*—Continued.

Date.	End of period.	Carbon dioxid.		Water.				
		Total amount in chamber.	Gain (+) or loss (−) over preceding period.	Total amount of vapor remaining in chamber.	Gain (+) or loss (−) over preceding period.	Change in weight of absorbers. Gain (+) or loss (−).	Amount absorbed by underclothes.	Total amount gained (+) or lost (−) during the period.
	Experiment No. 65.							
1904,		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 23–24	7 a. m. to 10 a. m	37.60	+ 3.96	63.03	+ 2.64	− 19.90	....	− 17.26
	10 a. m. to 1 p. m	32.09	− 5.51	55.92	− 7.11	− 19.90	....	− 27.01
	1 p. m. to 4 p. m	38.48	+ 6.39	60.23	+ 4.31	− 19.90	....	− 15.59
	4 p. m. to 7 p. m	33.37	− 5.11	54.74	− 5.49	− 19.90	....	− 25.39
	7 p. m. to 10 p. m	41.66	+ 8.29	55.10	+ .36	− 19.90	....	− 19.54
	10 p. m. to 1 a. m	42.51	+ .85	58.82	+ 3.72	− 19.90	....	− 16.18
	1 a. m. to 4 a. m	33.17	− 9.34	56.55	− 2.27	− 19.80	....	− 22.07
	4 a. m. to 7 a. m	29.48	− 3.69	51.66	− 4.89	− 19.80	....	− 24.69
	Total	....	− 4.16	....	− 8.73	−159.00	....	−167.73
	Experiment No. 66.							
Apr. 24–25	7 a. m. to 10 a. m	44.85	+ 15.37	52.46	+ .80	− 22.10	....	− 21.30
	10 a. m. to 1 p. m	43.35	− 1.50	50.71	− 1.75	− 22.10	....	− 23.85
	1 p. m. to 4 p. m	42.50	− .85	47.48	− 3.23	− 22.10	....	− 25.33
	4 p. m. to 7 p. m	46.93	+ 4.43	46.99	− .49	− 22.10	....	− 22.59
	7 p. m. to 10 p. m	40.98	− 5.95	47.46	+ .47	− 22.10	....	− 21.63
	10 p. m. to 1 a. m	37.02	− 3.96	47.52	+ .06	− 22.10	....	− 22.04
	1 a. m. to 4 a. m	30.28	− 6.74	48.44	+ .92	− 22.10	....	− 21.18
	4 a. m. to 7 a. m	36.93	+ 6.65	46.14	− 2.30	− 22.10	....	− 24.40
	Total	....	+ 7.45	....	− 5.52	−176.80	....	−182.32
	Experiment No. 67.							
Apr. 25–26	7 a. m. to 10 a. m	64.07	+ 27.14	49.59	+ 3.45	− 14.50	....	− 11.05
	10 a. m. to 1 p. m	51.74	− 12.33	50.39	+ .80	− 14.50	....	− 13.70
	1 p. m. to 4 p. m	56.86	+ 5.12	50.40	+ .01	− 14.50	....	− 14.49
	4 p. m. to 7 p. m	52.17	− 4.69	48.31	− 2.09	− 14.50	....	− 16.59
	7 p. m. to 10 p. m	44.77	− 7.40	44.70	− 3.61	− 14.50	....	− 18.11
	10 p. m. to 1 a. m	45.14	+ .37	49.52	+ 4.82	− 14.50	....	− 9.68
	1 a. m. to 4 a. m	34.57	− 10.57	48.25	− 1.27	− 14.50	....	− 15.77
	4 a. m. to 7 a. m	36.77	+ 2.20	45.48	− 2.77	− 14.50	....	− 17.27
	Total	....	− .16	....	− .66	−116.00	....	−116.66
Apr. 26–27	7 a. m. to 10 a. m	68.68	+ 31.91	47.56	+ 2.08	− 4.40	....	− 2.32
	10 a. m. to 1 p. m	62.89	− 5.79	47.73	+ .17	− 4.40	....	− 4.23
	1 p. m. to 4 p. m	72.10	+ 9.21	51.22	+ 3.49	− 4.40	....	− .91
	4 p. m. to 7 p. m	63.65	− 8.45	46.20	− 5.02	− 4.40	....	− 9.42
	7 p. m. to 10 p. m	54.83	− 8.82	46.87	+ .67	− 4.40	....	− 3.73
	10 p. m. to 1 a. m	53.51	− 1.32	47.95	+ 1.08	− 4.40	....	− 3.32
	1 a. m. to 4 a. m	42.89	− 10.62	47.21	− .74	− 4.30	....	− 5.04
	4 a. m. to 7 a. m	43.73	+ .84	44.64	− 2.57	− 4.30	....	− 6.87
	Total	....	+ 6.96	....	− .84	− 35.00	....	− 35.84
	Total, 2 days	....	+ 6.80	....	− 1.50	−151.00	....	−152.50

Table 109.—*Record of carbon dioxid in ventilating air current, metabolism experiments Nos. 56–58 and 60–67.*

Date.	Period.	Carbon dioxid.					(*f*) Carbon in carbon dioxid exhaled, $d\times\frac{3}{11}$.
		(*a*) Amount in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Amount absorbed from outcoming air.	(*d*) Corrected weight exhaled by subject, *b*+*c*.	(*e*) Volume exhaled by subject, *d*× 0.5091.	
	Preliminary to experiment No. 56.						
1903.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Apr. 27	1 a. m.	37.25					
	1 a. m. to 7 a. m.	42.55	+ 5.30	158.52	163.82	83.40	44.68
	Experiment No. 56.						
Apr. 27–28	7 a. m. to 1 p. m.	142.38	+ 99.83	593.87	693.70	353.16	189.19
	1 p. m. to 7 p. m.	117.28	− 25.10	705.97	680.87	346.63	185.69
	7 p. m. to 1 a. m.	48.38	− 68.90	306.66	237.76	121.04	64.84
	1 a. m. to 7 a. m.	40.53	− 7.85	171.13	163.28	83.13	44.53
	Total, 1 day		− 2.02	1,777.63	1,775.61	903.96	484.25
Apr. 28–29	7 a. m. to 10 a. m.	169.09	+128.56	215.00	343.56	174.91	93.70
	10 a. m. to 1 p. m.	151.04	− 18.05	428.77	410.72	209.10	112.01
	Total, 6 hours		+110.51	643.77	754.28	384.01	205.71
	1 p. m. to 4 p. m.	170.73	+ 19.69	340.93	360.62	183.59	98.35
	4 p. m. to 7 p. m.	91.04	− 79.69	373.25	293.56	149.45	80.06
	Total, 6 hours		− 60.00	714.18	654.18	333.04	178.41
	7 p. m. to 10 p. m.	53.18	− 37.86	174.00	136.14	69.31	37.13
	10 p. m. to 1 a. m.	41.87	− 11.31	114.79	103.48	52 68	28.22
	Total, 6 hours		− 49.17	288.79	239.62	121.99	65.35
	1 a. m. to 4 a. m.	33.61	− 8.26	95.45	87.19	44.39	23.78
	4 a. m. to 7 a. m.	38.15	+ 4.54	73.75	78.29	39.86	21.35
	Total, 6 hours		− 3.72	169.20	165.48	84.25	45.13
	Total, 1 day		− 2.38	1,815.94	1,813.56	923.29	494.60
Apr. 29–30	7 a. m. to 10 a. m.	158.16	+120.01	223.99	344.00	175.13	93.81
	10 a. m. to 1 p. m.	85.23	− 72.93	347.13	274.20	139.60	74.79
	Total, 6 hours		+ 47.08	571.12	618.20	314.73	168.60
	1 p. m. to 4 p. m.	171.02	+ 85.79	282.40	368.19	187.45	100.41
	4 p. m. to 7 p. m.	105.73	− 65.29	381.21	315.92	160.83	86.16
	Total, 6 hours		+ 20.50	663.61	684.11	348.28	186.57
	7 p. m. to 10 p. m.	56.24	− 49.49	179.05	129.56	65.96	35.33
	10 p. m. to 1 a. m.	44.96	− 11.28	114.50	103.22	52.55	28.15
	Total, 6 hours		− 60.77	293.55	232.78	118.51	63.48
	1 a. m. to 4 a. m.	39.90	− 5.06	93.37	88.31	44.96	24.08
	4 a. m. to 7 a. m.	35.49	− 4.41	78.42	74.01	37.68	20.18
	Total, 6 hours		− 9.47	171.79	162.32	82.64	44.26
	Total, 1 day		− 2.66	1,700.07	1,697.41	864.16	462.91
	Total, 3 days		− 7.06	5,293.64	5,286.58	2,691.41	1,441.76
	Preliminary to experiment No. 57.						
May 7	1 a. m.	42.37					
	1 a. m. to 4 a. m.	41.75	− .62	90.44	89.82	45.73	24.50
	4 a. m. to 7 a. m.	38.95	− 2.80	94.47	91.67	46.67	25.00
	Total, 6 hours		− 3.42	184.91	181.49	92.40	49.50

Table 109.—*Record of carbon dioxid in ventilating air current, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Carbon dioxid.					(*f*) Carbon in carbon dioxid exhaled, $d \times \frac{3}{11}$.
		(*a*) Amount in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Amount absorbed from outcoming air.	(*d*) Corrected weight exhaled by subject, *b*+*c*.	(*e*) Volume exhaled by subject, *d*×0.5091.	
	Experiment No. 57.						
1 0		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
May 7-8	7 a. m. to 10 a. m.	142.22	+103.27	283.64	386.91	196.98	105.52
	10 a. m. to 1 p. m.	135.80	− 6.42	471.85	465.43	236.95	126.94
	Total, 6 hours		+ 96.85	755.49	852.34	433.93	232.46
	1 p. m. to 4 p. m.	158.88	+ 23.08	319.43	342.51	174.37	93.41
	4 p. m. to 7 p. m.	114.45	− 44.43	483.50	439.07	223.53	119.75
	Total, 6 hours		− 21.35	802.93	781.58	397.90	213.16
	7 p. m. to 10 p. m.	75.76	− 38.69	203.86	165.17	84.09	45.05
	10 p. m to 1 a. m.	86.59	+ 10.83	105.07	115.90	59.00	31.61
	Total, 6 hours		− 27.86	308.93	281.07	143.09	76.66
	1 a. m. to 4 a. m.	56.42	− 30.17	117.85	87.68	44.64	23.91
	4 a. m. to 7 a. m.	50.94	− 5.48	95.69	90.21	45.93	24.60
	Total, 6 hours		− 35.65	213.54	177.89	90.57	48.51
	Total, 1 day		+ 11.99	2,080.89	2,092.88	1,065.49	570.79
May 8-9	7 a m. to 10 a. m	170.44	+119.50	211.90	331.40	168.72	90.38
	10 a. m. to 1 p. m.	92.79	− 77.65	469.59	391.94	199.54	106.89
	Total, 6 hours		+ 41.85	681.49	723.34	368.26	197.27
	1 p. m. to 4 p. m.	150.35	+ 57.56	304.96	362.52	184.56	98.87
	4 p. m. to 7 p. m.	107.06	− 43.29	465.46	422.17	214.93	115.14
	Total, 6 hours		+ 14.27	770.42	784.69	399.49	214.01
	7 p. m. to 10 p. m.	49.77	− 57.29	223.87	166.58	84.81	45.43
	10 p. m. to 1 a. m.	37.98	− 11.79	151.47	139.68	71.11	38.09
	Total, 6 hours		− 69.08	375.34	306.26	155.92	83.52
	1 a. m. to 4 a. m.	23.98	− 14.00	98.63	84.63	43.09	23.08
	4 a. m. to 7 a. m.	28.15	+ 4.17	85.71	89.88	45.76	24.51
	Total, 6 hours		− 9.83	184.34	174.51	88.85	47.59
	Total, 1 day		− 22.79	2,011.59	1,988.80	1,012.52	542 39
May 9-10	7 a. m. to 10 a. m.	189.13	+160.98	257.36	418.34	212.97	114.09
	10 a. m. to 1 p. m.	167.40	− 21.73	512.56	490.83	249.88	133.86
	Total, 6 hours		+139.25	769.92	909.17	462.85	247.95
	1 p. m. to 4 p. m.	210.46	+ 43.06	354.10	397.16	202.19	108.32
	4 p. m. to 7 p. m.	62.68	−147.78	349.19	201.41	102.54	54.93
	Total, 6 hours		−104.72	703.29	598.57	304.73	163.25
	7 p. m. to 10 p. m.	61.38	− 1.30	167.80	166.50	84.77	45.41
	10 p. m. to 1 a. m.	33.56	− 27.82	132.52	104.70	53.30	28.55
	Total, 6 hours		− 29.12	300.32	271.20	138.07	73.96
	1 a. m. to 4 a. m.	36.39	+ 2.83	83.42	86.25	43.91	23.52
	4 a. m. to 7 a. m.	28.79	− 7.60	95.42	87.82	44.71	23.95
	Total, 6 hours		− 4.77	178.84	174.07	88.62	47.47
	Total, 1 day		+ .64	1,952.37	1,953.01	994.27	532.63
	Total, 3 days		− 10.16	6,044.85	6,034.69	3,072.28	1,645.81

Table 109.—*Record of carbon dioxid in ventilating air current, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Carbon dioxid.					(f) Carbon in carbon dioxid exhaled, $d\times\frac{3}{11}$.
		(a) Amount in chamber at end of period.	(b) Gain (+) or loss (−) over preceding period.	(c) Amount absorbed from outcoming air.	(d) Corrected weight exhaled by subject, $b+c$.	(e) Volume exhaled by subject, $d\times0.5091$.	
	Preliminary to experiment No. 58.						
1903.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Nov. 10	1 a. m.	37.31					
	1 a. m. to 7 a. m.	85.80	+ 48.49	69.34	117.83	59.99	32.14
	Experiment No. 58.						
Nov. 10–11.	7 a. m. to 1 p. m.	98.46	+ 12.66	120.12	132.78	67.60	36.21
	1 p. m. to 7 p. m.	112.78	+ 14.32	172.73	187.05	95.23	51.01
	7 p. m. to 1 a. m.	114.23	+ 1.45	166.92	168.37	85.72	45.92
	1 a. m. to 7 a. m.	98.04	− 16.19	156.06	139.87	71.21	38.15
	Total, 1 day		+ 12.24	615.83	628.07	319.76	171.29
Nov. 11–12.	7 a. m. to 1 p. m.	85.02	− 13.02	173.56	160.54	81.73	43.79
	1 p. m. to 7 p. m.	33.05	− 51.97	231.44	179.47	91.37	48.95
	7 p. m. to 1 a. m.	73.08	+ 40.03	127.97	168.00	85.53	45.82
	1 a. m. to 7 a. m.	26.36	− 46.72	183.25	136.53	69.51	37.24
	Total, 1 day		− 71.68	716.22	644.54	328.14	175.80
Nov. 12–13.	7 a. m. to 1 p. m.	90.06	+ 63.70	120.44	184.14	93.75	50.22
	1 p. m. to 7 p. m.	47.80	− 42.26	248.67	206.41	105.08	56.29
	7 p. m. to 1 a. m.	102.78	+ 54.98	116.56	171.54	87.33	46.78
	1 a. m. to 7 a. m.	65.47	− 37.31	181.49	144.18	73.40	39.32
	Total, 1 day		+ 39.11	667.16	706.27	359.56	192.61
	Total, 3 days		− 20.33	1,999.21	1,978.88	1,007.46	539.70
	Preliminary to experiment No. 60.						
1904. Jan. 26–27.	10 p. m.	5.86					
	10 p. m. to 1 a. m.	2.28	− 3.58	47.94	44.36	22.58	12.10
	1 a. m. to 4 a. m.	1.61	− .67	60.87	60.20	30.65	16.42
	4 a. m. to 7 a. m.	1.87	+ .26	61.48	61.74	31.43	16.84
	Total, 8 hours		− 3.99	170.29	166.30	84.66	45.36
	Experiment No. 60.						
Jan. 27–28.	7 a. m. to 10 a. m.	8.10	+ 6.23	120.55	126.78	64.54	34.58
	10 a. m. to 1 p. m.	7.40	− .70	98.18	97.48	49.63	26.59
	Total, 6 hours		+ 5.53	218.73	224.26	114.17	61.17
	1 p. m. to 4 p. m.	8.35	+ .95	106.00	106.95	54.45	29.17
	4 p. m. to 7 p. m.	15.84	+ 7.49	91.23	98.72	50.26	26.92
	Total, 6 hours		+ 8.44	197.23	205.67	104.71	56.09
	7 p. m. to 10 p. m.	12.45	− 3.39	122.98	119.59	60.89	32.62
	10 p. m. to 1 a. m.	11.45	− 1.00	85.45	84.45	42.99	23.03
	Total, 6 hours		− 4.39	208.43	204.04	103.88	55.65
	1 a. m. to 4 a. m.	7.35	− 4.10	67.96	63.86	32.51	17.42
	4 a. m. to 7 a. m.	9.62	+ 2.27	70.58	72.85	37.08	19.87
	Total, 6 hours		− 1.83	138.54	136.71	69.59	37.29
	Total, 1 day		+ 7.75	762.93	770.68	392.35	210.20
Jan. 28–29.	7 a. m. to 10 a. m.	109.85	+100.23	24.69	124.92	63.59	34.06
	10 a. m. to 1 p. m.	179.88	+ 70.03	32.68	102.71	52.28	28.01
	Total, 6 hours		+170.26	57.37	227.63	115.87	52.07

TABLE 109.—*Record of carbon dioxid in ventilating air current, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Carbon dioxid.					
		(*a*) Amount in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Amount absorbed from outcoming air.	(*d*) Corrected weight. exhaled by subject, *b*+*c*.	(*e*) Volume exhaled by subject $d\times0.5091$.	(*f*) Carbon in carbon dioxid exhaled, $d\times\frac{3}{11}$.
	Experiment No. 60—Continued.						
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Jan. 28–29..	1 p. m. to 4 p. m......	203.71	+ 23.83	84.73	108.56	55.26	29.60
	4 p. m. to 7 p. m......	198.18	− 5.53	105.02	99.49	50.65	27.13
	Total, 6 hours...	....	+ 18.30	189.75	208.05	105.91	56.73
	7 p. m. to 10 p. m.....	221.86	+ 23.68	103.20	126.88	64.59	34.61
	10 p. m. to 1 a. m.....	209.75	− 12.11	83.04	70.93	36.10	19.35
	Total, 6 hours...	....	+ 11.57	186.24	197.81	100.69	53.96
	1 a. m. to 4 a. m......	203.63	− 6.12	70.29	64.17	32.66	17.50
	4 a. m. to 7 a. m......	221.71	+ 18.08	45.69	63.77	32.46	17.39
	Total, 6 hours...	....	+ 11.96	115.98	127.94	65.12	34.89
	Total, 1 day....	....	+212.09	549.34	761.43	387.59	207.65
Jan. 29–30..	7 a. m. to 10 a. m......	148.77	− 72.94	191.44	118.50	60.33	32.32
	10 a. m. to 1 p. m.....	44.16	−104.61	220.85	116.24	59.18	31.70
	Total, 6 hours...	....	177.55	412.29	234.74	119.51	64.02
	1 p. m. to 4 p. m......	79.64	+ 35.48	78.22	113.70	57.88	31.01
	4 p. m. to 7 p. m......	39.15	− 40.49	164.01	123.52	62.88	33.68
	Total, 6 hours...	....	− 5.01	242.23	237.22	120.76	64.69
	7 p. m. to 10 p. m.....	84.08	+ 44.93	73.90	118.83	60.48	32.40
	10 p. m. to 1 a. m.....	24.57	− 59.51	142.10	82.59	42.04	22.52
	Total, 6 hours...	....	− 14.58	216.00	201.42	102.52	54.92
	1 a. m. to 4 a. m.......	24.48	− .09	64.95	64.86	33.04	17.69
	4 a. m. to 7 a. m.......	24.87	+ .39	69.15	69.54	35.40	18.97
	Total, 6 hours...	....	+ .30	134.10	134.40	68.44	36.66
	Total, 1 day.....	....	−196.84	1,004.62	807.78	411.23	220.29
	Total, 3 days....	....	+ 23.00	2,316.89	2,339.89	1,191.17	638.14
	Experiment No. 61.						
Jan. 30–31..	7 a. m. to 10 a. m......	157.40	+132.53	231.19	363.72	185.18	99.19
	10 a. m. to 1 p. m.....	117.48	− 39.92	436.43	396.51	201.85	108.14
	Total, 6 hours...	....	+ 92.61	667.62	760.23	387.03	207.33
	1 p. m. to 4 p. m......	104.08	− 13.40	280.84	267.44	136.13	72.93
	4 p. m. to 7 p. m......	51.20	− 52.88	264.01	211.13	107.49	57.58
	Total, 6 hours...	....	− 66.28	544.85	478.57	243.62	130.51
	7 p. m. to 10 p. m.....	38.42	− 12.78	130.74	117.96	60.06	32.17
	10 p. m. to 1 a. m.....	32.15	− 6.27	95.99	89.72	45.68	24.47
	Total, 6 hours...	....	− 19.05	226.73	207.68	105.74	56.64
	1 a. m. to 4 a. m......	32.21	+ .06	82.48	82.54	42.02	22.51
	4 a. m. to 7 a. m......	29.50	− 2.71	73.32	70.61	35.95	19.26
	Total, 6 hours...	....	− 2.65	155.80	153.15	77.97	41.77
	Total, 1 day.......	....	+ 4.63	1,595.00	1,599.63	814.36	436.25

Table 109.—*Record of carbon dioxid in ventilating air current, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Carbon dioxid.					(*f*) Carbon in carbon dioxid exhaled, $d \times \frac{3}{11}$.
		(*a*) Amount in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Amount absorbed from outcoming air.	(*d*) Corrected weight exhaled by subject, *b*+*c*.	(*e*) Volume exhaled by subject, *d*×0.5091.	
	Preliminary to experiment No. 62.						
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Apr. 15–16.	7 p. m.	39.51	....	....	....	....	....
	7 p. m. to 10 p. m.	47.74	+ 8.23	142.27	150.50	76.62	41.05
	10 p. m. to 1 a. m.	30.77	− 16.97	119.72	102.75	52.31	28.02
	Total, 6 hours	....	− 8.74	261.99	253.25	128.93	69.07
	1 a. m. to 4 a. m.	28.62	− 2.15	69.27	67.12	34.17	18.31
	4 a. m. to 7 a. m.	29.19	+ .57	79.35	79.92	40.69	21.80
	Total, 6 hours	....	− 1.58	148.62	147.04	74.86	40.11
	Total, 12 hours	....	− 10.32	410.61	400.29	203.79	109.18
	Experiment No. 62.						
Apr. 16–17.	7 a. m. to 10 a. m.	156.06	+126.87	210.64	337.51	171.83	92.05
	10 a. m. to 1 p. m.	95.64	− 60.42	372.08	311.66	158.67	85.00
	Total, 6 hours	....	+ 66.45	582.72	649.17	330.50	177.05
	1 p. m. to 4 p. m.	129.23	+ 33.59	286.02	319.61	162.71	87.16
	4 p. m. to 7 p. m.	80.04	− 49.19	372.93	323.74	164.82	88.29
	Total, 6 hours	....	− 15.60	658.95	643.35	327.53	175.45
	7 p. m. to 10 p. m.	48.72	− 31.32	145.25	113.93	58.00	31.07
	10 p. m. to 1 a. m.	35.94	− 12.78	127.26	114.48	58.28	31.22
	Total, 6 hours	....	− 44.10	272.51	228.41	116.28	62.29
	1 a. m. to 4 a. m.	31.04	− 4.90	99.29	94.39	48.05	25.75
	4 a. m. to 7 a. m.	28.64	− 2.40	83.02	80.62	41.04	21.98
	Total, 6 hours	....	− 7.30	182.31	175.01	89.09	47.73
	Total, 1 day	....	− .55	1,696.49	1,695.94	863.40	462.52
Apr. 17–18.	7 a. m. to 10 a. m.	154.71	+126.07	216.23	342.30	174.26	93.36
	10 a. m. to 1 p. m.	93.63	− 61.08	393.98	332.90	169.48	90.80
	Total, 6 hours	....	+ 64.99	610.21	675.20	343.74	184.16
	1 p. m. to 4 p. m.	133.08	+ 39.45	282.85	322.30	164.08	87.90
	4 p. m. to 7 p. m.	85.06	− 48.02	362.76	314.74	160.23	85.84
	Total, 6 hours	....	− 8.57	645.61	637.04	324.31	173.74
	7 p. m. to 10 p. m.	52.26	− 32.80	171.72	138.92	70.72	37.89
	10 p. m. to 1 a. m.	35.57	− 16.69	124.49	107.80	54.88	29.40
	Total, 6 hours	....	− 49.49	296.21	246.72	125.60	67.29
	1 a. m. to 4 a. m.	31.73	− 3.84	85.67	81.83	41.66	22.32
	4 a. m. to 7 a. m.	31.86	+ .13	83.50	83.63	42.58	22.81
	Total, 6 hours	....	− 3.71	169.17	165.46	84.24	45.13
	Total, 1 day	....	+ 3.22	1,721.20	1,724.42	877.89	470.32
Apr. 18–19.	7 a. m. to 10 a. m.	158.77	+126.91	203.90	330.81	168.42	90.24
	10 a. m. to 1 p. m.	114.23	− 44.54	371.36	326.82	166.38	89.14
	Total, 6 hours	....	+ 82.37	575.26	657.63	334.80	179.38
	1 p. m. to 4 p. m.	151.21	+ 36.98	298.90	335.88	171.00	91.60
	4 p. m. to 7 p. m.	92.70	− 58.51	350.85	292.34	148.83	79.72
	Total, 6 hours	....	− 21.53	649.75	628.22	319.83	171.32

Table 109.—*Record of carbon dioxid in ventilating air current, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Carbon dioxid.					
		(*a*) Amount in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Amount absorbed from outcoming air.	(*d*) Corrected weight exhaled by subject, $b+c$.	(*e*) Volume exhaled by subject, $d \times 0.5091$.	(*f*) Carbon in carbon dioxid exhaled, $d \times \frac{3}{11}$.
	Experiment No. 62—Continued.						
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Apr. 18–19.	7 p. m. to 10 p. m	65.03	− 27.67	178.44	150.77	76.76	41.12
	10 p. m. to 1 a. m	39.63	− 25.40	118.41	93.01	47.35	25.37
	Total, 6 hours...	....	− 53.07	296.85	243.78	124.11	66.49
	1 a. m. to 4 a. m.......	40.76	+ 1.13	84.71	85.84	43.70	23.41
	4 a. m. to 7 a. m.......	34.53	− 6.23	92.78	86.55	44.06	23.60
	Total, 6 hours...	....	− 5.10	177.49	172.39	87.76	47.01
	Total, 1 day.....	....	+ 2.67	1,699.35	1,702.02	866.50	464.20
	Total, 3 days....	....	+ 5.34	5,117.04	5,122.38	2,607.79	1,397.04
	Experiment No. 63.						
Apr. 19–20..	7 a. m. to 10 a. m......	161.75	+127.22	202.07	329.29	167.64	89.80
	10 a. m. to 1 p. m......	94.79	− 66.96	368.22	301.26	153.37	82.16
	Total, 6 hours...	....	+ 60.26	570.29	630.55	321.01	171.96
	1 p. m. to 4 p. m	128.09	+ 33.30	288.82	322.12	163.99	87.85
	4 p. m. to 7 p. m	66.20	− 61.89	318.37	256.48	130.57	69.94
	Total, 6 hours...	....	− 28.59	607.19	578.60	294.56	157.79
	7 p. m. to 10 p. m	46.36	− 19.84	142.03	122.19	62.21	33.32
	10 p. m. to 1 a. m	34.89	− 11.47	115.47	104.00	52.95	28.37
	Total, 6 hours...	....	− 31.31	257.50	226.19	115.16	61.69
	1 a. m. to 4 a. m.......	32.01	− 2.88	86.59	83.71	42.62	22.83
	4 a. m. to 7 a. m.......	30.17	− 1.84	84.48	82.64	42.07	22.54
	Total, 6 hours...	....	− 4.72	171.07	166.35	84.69	45.37
	Total, 1 day.....	....	− 4.36	1,606.05	1,601.69	815.42	436.81
Apr. 20–21..	7 a. m. to 10 a. m......	148.08	+117.91	203.53	321.44	163.65	87.66
	10 a. m. to 1 p. m......	95.15	− 52.93	356.14	303.21	154.36	82.70
	Total, 6 hours...	....	+ 64.98	559.67	624.65	318.01	170.36
	1 p. m. to 4 p. m	116.31	+ 21.16	280.04	301.20	153.34	82.15
	4 p. m. to 7 p. m	71.15	− 45.16	308.44	263.28	134.04	71.80
	Total, 6 hours...	....	− 24.00	588.48	564.48	287.38	153.95
	7 p. m. to 10 p. m	44.95	− 26.20	149.97	123.77	63.01	33.76
	10 p. m. to 1 a. m	37.92	− 7.03	116.81	109.78	55.89	29.94
	Total, 6 hours...	....	− 33.23	266.78	233.55	118.90	63.70
	1 a. m. to 4 a. m.......	27.10	− 10.82	80.99	70.17	35.72	19.14
	4 a. m. to 7 a. m.......	32.94	+ 5.84	82.18	88.02	44.81	24.00
	Total, 6 hours...	....	− 4.98	163.17	158.19	80.53	43.14
	Total, 1 day.....	....	+ 2.77	1,578.10	1,580.87	804.82	431.15
Apr. 21–22..	7 a. m. to 10 a. m......	136.81	+103.87	203.43	307.30	156.45	83.81
	10 a. m. to 1 p. m	87.19	− 49.62	336.95	287.33	146.28	78.36
	Total, 6 hours...	....	+ 54.25	540.38	594.63	302.73	162.17
	1 p. m. to 4 p. m	120.98	+ 33.79	287.55	321.34	163.59	87.64
	4 p. m. to 7 p. m	69.44	− 51.54	314.35	262.81	133.80	71.68
	Total, 6 hours...	....	− 17.75	601.90	584.15	297.39	159.32

Table 109.—*Record of carbon dioxid in ventilating air current, metabolism experiments Nos. 56–58, and 60–67*—Continued.

Date.	Period.	Carbon dioxid.					
		(*a*) Amount in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Amount absorbed from outcoming air.	(*d*) Corrected weight exhaled by subject, *b*+*c*.	(*e*) Volume exhaled by subject, $d\times0.5091$.	(*f*) Carbon in carbon dioxid exhaled, $d\times\frac{3}{11}$.
	Experiment No. 63—Continued.						
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Apr.21–22..	7 p. m. to 10 p. m	45.29	− 24.15	148.92	124.77	63.52	34.03
	10 p. m. to 1 a. m	35.99	− 9.30	116.46	107.16	54.56	29.22
	Total, 6 hours...	....	− 33.45	265.38	231.93	118.08	63.25
	1 a. m. to 4 a. m.......	38.13	+ 2.14	84.37	86.51	44.04	23.59
	4 a. m. to 7 a. m.......	30.95	− 7.18	88.39	81.21	41.34	22.15
	Total, 6 hours...	....	− 5.04	172.76	167.72	85.38	45.74
	Total, 1 day.....	....	− 1.99	1,580.42	1,578.43	803.58	430.48
	Total, 3 days....	....	− 3.58	4,764.57	4,760.99	2,423.82	1,298.44
	Experiment No. 64.						
Apr.22–23..	7 a. m. to 10 a. m......	157.42	+126.47	242.02	368.49	187.60	100.50
	10 a. m. to 1 p. m	91.95	− 65.47	370.13	304.66	155.10	83.09
	Total, 6 hours...	....	+ 61.00	612.15	673.15	342.70	183.59
	1 p. m. to 4 p. m	131.11	+ 39.16	352.91	392.07	199.60	106.91
	4 p. m. to 7 p. m	90.13	− 40.98	377.39	336.41	171.27	91.75
	Total, 6 hours...	....	− 1.82	730.30	728.48	370.87	198.66
	7 p. m. to 10 p. m	137.85	+ 47.72	336.35	384.07	195.53	104.75
	10 p. m. to 1 a. m	66.63	− 71.22	320.90	249.68	127.11	68.10
	Total, 6 hours...	....	− 23.50	657.25	633.75	322.64	172.85
	1 a. m. to 4 a. m.......	61.67	− 4.96	228.40	223.44	113.75	60.94
	4 a. m. to 7 a. m.......	33.64	− 28.03	113.22	85.19	43.37	23.23
	Total, 6 hours...	....	− 32.99	341.62	308.63	157.12	84.17
	Total, 1 day.....	....	+ 2.69	2,341.32	2,344.01	1,193.33	639.27
	Experiment No. 65.						
Apr.23–24..	7 a. m. to 10 a. m......	37.60	+ 3.96	109.13	113.09	57.57	30.84
	10 a. m. to 1 p. m	32.09	− 5.51	91.52	86.01	43.79	23.46
	Total, 6 hours...	....	− 1.55	200.65	199.10	101.36	54.30
	1 p. m. to 4 p. m	38.48	+ 6.39	104.10	110.49	56.25	30.13
	4 p. m. to 7 p. m	33.37	− 5.11	101.61	96.50	49.13	26.32
	Total, 6 hours...	....	+ 1.28	205.71	206.99	105.38	56.45
	7 p. m. to 10 p. m.	41.66	+ 8.29	111.59	119.88	61.03	32.69
	10 p. m. to 1 a. m	42.51	+ .85	125.94	126.79	64.55	34.58
	Total, 6 hours...	....	+ 9.14	237.53	246.67	125.58	67.27
	1 a. m. to 4 a. m.......	33.17	− 9.34	94.25	84.91	43.23	23.16
	4 a. m. to 7 a. m.......	29.48	− 3.69	81.06	77.37	39.39	21.10
	Total, 6 hours...	....	− 13.03	175.31	162.28	82.62	44.26
	Total, 1 day.....	....	− 4.16	819.20	815.04	414.94	222.28
	Experiment No. 66.						
Apr.24–25..	7 a. m. to 10 a. m......	44.85	+ 15.37	114.93	130.30	66.34	35.54
	10 a. m. to 1 p. m	43.35	− 1.50	120.55	119.05	60.61	32.47
	Total, 6 hours...	....	+ 13.87	235.48	249.35	126.95	68.01

TABLE 109.—*Record of carbon dioxid in ventilating air current, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Carbon dioxid.					(*f*) Carbon in carbon dioxid exhaled, $d \times \frac{3}{11}$.
		(*a*) Amount in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Amount absorbed from outcoming air.	(*d*) Corrected weight exhaled by subject, $b+c$.	(*e*) Volume exhaled by subject, $d \times 0.5091$.	
	Experiment No. 66—Continued.						
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Grams.*
Apr. 24–25..	1 p. m. to 4 p. m	42.50	− .85	114.53	113.68	57.87	31.00
	4 p. m. to 7 p. m......	46.93	+ 4.43	114.19	118.62	60.39	32.35
	Total, 6 hours...	....	+ 3.58	228.72	232.30	118.26	63.35
	7 p. m. to 10 p. m.....	40.98	− 5.95	113.13	107.18	54.57	29.23
	10 p. m. to 1 a. m.....	37.02	− 3.96	101.07	97.11	49.44	26.49
	Total, 6 hours...	....	− 9.91	214.20	204.29	104.01	55.72
	1 a. m. to 4 a. m.......	30.28	− 6.74	81.35	74.61	37.98	20.35
	4 a. m. to 7 a. m.......	36.93	+ 6.65	72.54	79.19	40.32	21.60
	Total, 6 hours...	....	− .09	153.89	153.80	78.30	41.95
	Total, 1 day.....	....	+ 7.45	832.29	839.74	427.52	229.03
	Experiment No. 67.						
Apr. 25-26..	7 a. m. to 10 a. m.....	64.07	+ 27.14	122.97	150.11	76 42	40.94
	10 a. m. to 1 p. m.....	51.74	− 12.33	150.67	138.34	70.43	37.73
	Total, 6 hours...	....	+ 14.81	273.64	288.45	146.85	78.67
	1 p. m. to 4 p. m......	56.86	+ 5.12	132.29	137.41	69.96	37.48
	4 p. m. to 7 p. m......	52.17	− 4.69	143.36	138.67	70.60	37.82
	Total, 6 hours...	....	+ .43	275.65	276.08	140.56	75.30
	7 p. m. to 10 p. m.....	44.77	− 7.40	125.29	117.89	60.02	32.15
	10 p. m. to 1 a. m.....	45.14	+ .37	114.75	115.12	58.61	31.40
	Total, 6 hours...	....	− 7.03	240.04	233.01	118.63	63.55
	1 a. m. to 4 a. m.......	34.57	− 10.57	88.83	78.26	39.84	21.34
	4 a. m. to 7 a. m.......	36.77	+ 2.20	73.55	75.75	38.56	20.66
	Total, 6 hours...	....	− 8.37	162.38	154.01	78.40	42.00
	Total, 1 day.....	....	− .16	951.71	951.55	484.44	259.52
Apr. 26–27..	7 a. m. to 10 a. m......	68.68	+ 31.91	123.88	155.79	79.31	42.49
	10 a. m. to 1 p. m.....	62.89	− 5.79	142.69	136.90	69.70	37.33
	Total, 6 hours...	....	+ 26.12	266.57	292.69	149.01	79.82
	1 p. m. to 4 p. m......	72.10	+ 9.21	156.18	165.39	84.20	45.11
	4 p. m. to 7 p. m......	63.65	− 8.45	140.98	132.53	67.47	36.14
	Total, 6 hours...	....	+ .76	297.16	297.92	151.67	81.25
	7 p. m. to 10 p. m.....	54.83	− 8.82	120.92	112.10	57.07	30.57
	10 p. m. to 1 a. m.....	53.51	− 1.32	103.08	101.76	51.81	27.75
	Total, 6 hours...	....	− 10.14	224.00	213.86	108.88	58.32
	1 a. m. to 4 a. m.......	42.89	− 10.62	83.93	73.31	37.32	19.99
	4 a. m. to 7 a. m.......	43.73	+ .84	73 46	74.30	37.83	20.26
	Total, 6 hours...	....	− 9.78	157.39	147.61	75.15	40.25
	Total, 1 day.....	....	+ 6.96	945.12	952.08	484.71	259.64
	Total, 2 days....	....	+ 6.80	1,896.83	1,903.63	969.15	519.16

TABLE 110.—*Carbon dioxid eliminated from lungs and skin by 3-hour periods, metabolism experiments Nos. 56–58 and 60–67.*

Kind and number of experiment.	Day.	7 a. m. to 10 a. m.	10 a. m. to 1 p. m.	Total, 6 hours.	1 p. m. to 4 p. m.	4 p. m. to 7 p. m.	Total, 6 hours.	7 p. m. to 10 p. m.	10 p. m. to 1 a. m.	Total, 6 hours.	1 a. m. to 4 a. m.	4 a. m. to 7 a. m.	Total, 6 hours.	Total, 1 day.
Rest experiments, cabohydrate diet.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 58 [a]	1	....	....	132.78	....	....	187.05	....	....	168.37	....	....	139.87	628.07
No. 58	2	....	....	160.54	....	....	179.47	....	....	168.00	....	....	136.53	644.54
No. 58	3	....	....	184.14	....	....	206.41	....	....	171.54	....	....	144.18	706.27
Average per day	......		....	159.15	....	....	190.98	....	....	169.31	....	......	140.19	659.63
No. 60	1	126.78	97.48	224.26	106.95	98.72	205.67	119.59	84.45	204.04	63.86	72.85	136.71	770.68
No. 60	2	124.92	102.71	227.63	108.56	99.49	208.05	126.88	70.93	197.81	64.17	63.77	127.94	761.43
No. 60	3	118.50	116.24	234.74	113.70	123.52	237.22	118.83	82.59	201.42	64.86	69.54	134.40	807.78
Average per day	......	123.40	105.47	228.87	109.74	107.24	216.98	121.77	79.32	201.09	64.30	68.72	133.02	779.96
No. 65	1	113.09	86.01	199.10	110.49	96.50	206.99	119.88	126.79	246.67	84.91	77.37	162.28	815.04
No. 66	1	130.30	119.05	249.35	113.68	118.62	232.30	107.18	97.11	204.29	74.61	79.19	153.80	839.74
No. 67	1	150.11	138.34	288.45	137.41	138.67	276.08	117.89	115.12	233.01	78.26	75.75	154.01	951.55
No. 67	2	155.79	136.90	292.69	165.39	132.53	297.92	112.10	101.76	213.86	73.31	74.30	147.61	952.08
Average per day	......	152.95	137.62	290.57	151.40	135.60	287.00	115.00	108.44	223.44	75.79	75.03	150.81	951.82
Average of Nos. 65, 66, and 67	......	137.32	120.08	257.40	131.74	121.58	253.32	114.26	110.20	224.46	77.77	76.65	154.42	889.60
Average of Nos. 58, 60, 65, 66, and 67	......	[b] 131.36	[b] 113.82	219.37	[b] 122.31	[b] 115.44	223.72	[b] 117.48	[b] 96.96	200.90	[b] 72.00	[b] 73.25	143.73	787.72
Work experiments, carbohydrate diet.														
No. 57	1	386.91	465.43	852.34	342.51	439.07	781.58	165.17	115.90	281.07	87.68	90.21	177.89	2,092.88
No. 57	2	331.40	391.94	723.34	362.52	422.17	784.69	166.58	139.68	306.26	84.63	89.88	174.51	1,988.80
No. 57	3	418.34	490.83	909.17	397.16	201.41	598.57	166.50	104.70	271.20	86.25	87.82	174.07	1,953.01
Average per day	......	378.88	449.40	828.28	367.40	354.21	721.61	166.08	120.10	286.18	86.19	89.30	175.49	2,011.56
No. 61	1	363.72	396.51	760.23	267.44	211.13	478.57	117.96	89.72	207.68	82.54	70.61	153.15	1,599.63
No. 62	1	337.51	311.66	649.17	319.61	323.74	643.35	113.93	114.48	228.41	94.39	80.62	175.01	1,695.94
No. 62	2	342.30	332.90	675.20	322.30	314.74	637.04	138.92	107.80	246.72	81.83	83.63	165.46	1,724.42
No. 62	3	330.81	326.82	657.63	335.88	292.34	628.22	150.77	93.01	243.78	85.84	86.55	172.39	1,702.02
Average per day	......	336.88	323.79	660.67	325.93	310.27	636.20	134.54	105.10	239.64	87.35	83.60	170.95	1,707.46
Average Nos. 57, 61, and 62	......	358.71	388.01	746.72	335.35	314.94	650.29	145.69	109.33	255.02	86.16	84.19	170.35	1,822.38

Work experiment, fat diet.														
No. 56 [c]	1	....	....	693.70	....	....	680.87	....	....	237.76	....	....	163.28	1,775.61
No. 56	2	343.56	410.72	754.28	360.62	293.56	654.18	136.14	103.48	239.62	87.19	78.29	165.48	1,813.56
No. 56	3	344.00	274.20	618.20	368.19	315.92	684.11	129.56	103.22	232.78	88.31	74.01	162.32	1,697.41
Average per day	......	[d] 343.78	[d] 342.46	688.73	[d] 364.41	[d] 304.74	673.05	[d] 132.85	[d] 103.35	236.72	[d] 87.75	[d] 76.15	163.69	1,762.19
No. 63	1	329.29	301.26	630.55	322.12	256.48	578.60	122.19	104.00	226.19	83.71	82.64	166.35	1,601.69
No. 63	2	321.44	303.21	624.65	301.20	263.28	564.48	123.77	109.78	233.55	70.17	88.02	158.19	1,580.87
No. 63	3	307.30	287.33	594.63	321.34	262.81	584.15	124.77	107.16	231.93	86.51	81.21	167.72	1,578.43
Average per day	......	319.34	297.27	616.61	314.88	260.86	575.74	123.58	106.98	230.56	80.13	83.96	164.09	1,587.00
Average Nos. 56, and 63	......	[e] 329.12	[e] 315.34	652.67	[e] 334.69	[e] 278.41	624.40	[e] 127.29	[e] 105.53	233.64	[e] 83.18	[e] 80.83	163.89	1,674.60
Average Nos. 56, 57, 61, 62, and 63	......	[e] 346.38	[e] 357.73	703.31	[e] 335.07	[e] 299.72	638.34	[e] 138.02	[e] 107.74	245.15	[e] 84.92	[e] 82.79	167.37	1,754.17
Severe work, fat diet.														
No. 64	1	368.49	304.66	673.15	392.07	336.41	728.48	384.07	249.68	633.75	223.44	85.19	308.63	2,344.01
Average Nos. 56, 57, and 61-64	......	[e] 348.08	[e] 353.65	701.16	[e] 339.46	[e] 302.54	644.78	[e] 156.95	[e] 118.66	272.91	[e] 95.58	[e] 82.98	177.46	1,796.31

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[a] In No. 58 records were made only by 6-hour periods.
[b] Average of Nos. 60, 65, 66, and 67.
[c] During the first day of No. 56 records were made only by 6-hour periods
[d] Average of second and third days.
[e] First day of No. 56 not included in 3-hour average.

TABLE 111.—*Record of water of respiration and perspiration, metabolism experiments Nos. 56–58 and 60–67.*

Date.	Period.	(*a*) Total amount of vapor in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) or loss.	(*d*) Amount in underclothes. *	(*e*) Total amount gained (+) or lost (−) during period, *f*+*c*+*a*.	(*f*) Total amount in outgoing air.	(*g*)* Total water of respiration and perspiration,* *e*+*f*.
	Preliminary to experiment No. 56.							
1903.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 27	1 a. m.	56.84						
	1 a. m. to 7 a. m	54.64	− 2.20			− 2.20	270.14	267.94
	Experiment No. 56.							
Apr. 27–28	7 a. m. to 1 p. m	67.95	+13.31	+1,003.82	55.10	+1,072.23	270.12	1,342.35
	1 p. m. to 7 p. m	68.82	+ .87	+1,190.02	55.00	+1,245.89	307.59	1,553.48
	7 p. m. to 1 a. m	64.04	− 4.87	+ 75.30		+ 70.52	347.51	418.03
	1 a. m. to 7 a. m	63.14	− .90	+ 74.46		+ 73.56	314.85	388.41
	Total, 1 day		+ 8.50	+2,343.60	110.10	+2,462.20	1,240.07	3,702.27
Apr. 28–29	7 a. m. to 10 a. m	66.02	+ 2.88	+ 679.41	39.70	+ 721.99	165.25	887.24
	10 a. m. to 1 p. m	69.96	+ 3.94	+ 679.41	39.80	+ 723.15	161.02	884.17
	Total, 6 hours		+ 6.82	+1,358.82	79.50	+1,445.14	326.27	1,771.41
	1 p. m. to 4 p. m	68.22	− 1.74	+ 621.91	39.70	+ 659.87	173.77	833.64
	4 p. m. to 7 p. m	64.97	− 3.25	+ 621.91	39.70	+ 658.36	173.03	831.39
	Total, 6 hours		− 4.99	+1,243.82	79.40	+1,318.23	346.80	1,665.03
	7 p. m. to 10 p. m	66.47	+ 1.50	+ 16.39		+ 17.89	170.16	188.05
	10 p. m. to 1 a. m	68.60	+ 2.13	+ 16.39		+ 18.52	170.66	189.18
	Total, 6 hours		+ 3.63	+ 32.78		+ 36.41	340.82	377.23
	1 a. m. to 4 a. m	68.71	+ .11	+ 15.89		+ 16.00	175.81	191.81
	4 a. m. to 7 a. m	63.70	− 5.01	+ 15.89		+ 10.88	163.42	174.30
	Total, 6 hours		− 4.90	+ 31.78		+ 26.88	339.23	366.11
	Total, 1 day		+ .56	+2,667.20	158.90	+2,826.66	1,353.12	4,179.78
Apr. 29–30	7 a. m. to 10 a. m	65.21	+ 1.51	+ 533.62	51.00	+ 586.13	154.38	740.51
	10 a. m. to 1 p. m	66.30	+ 1.09	+ 533.62	51.00	+ 585.71	159.77	745.48
	Total, 6 hours		+ 2.60	+1,067.24	102.00	+1,171.84	314.15	1,485.99
	1 p. m. to 4 p. m	67.43	+ 1.13	+ 638.33	51.00	+ 690.46	159.00	849.46
	4 p. m. to 7 p. m	66.77	− .66	+ 638.32	50.90	+ 688.56	161.81	850.37
	Total, 6 hours		+ .47	+1,276.65	101.90	+1,379.02	320.81	1,699.83
	7 p. m. to 10 p. m	62.62	− 4.15	+ 28.83		+ 24.68	153.38	178.06
	10 p. m. to 1 a. m	69.79	+ 7.17	+ 28.83		+ 36.00	155.53	191.53
	Total, 6 hours		+ 3.02	+ 57.66		+ 60.68	308.91	369.59
	1 a. m. to 4 a. m	67.11	− 2.68	+ 28.33		+ 25.65	154.25	179.90
	4 a. m. to 7 a. m	60.37	− 6.74	+ 28.32		+ 21.58	150.25	171.83
	Total, 6 hours		− 9.42	+ 56.65		+ 47.23	304.50	351.73
	Total, 1 day		− 3.33	+2,458.20	203.90	+2,658.77	1,248.37	3,907.14
	Total, 3 days		+ 5.73	+7,469.00	472.90	+7,947.63	3,841.56	11,789.19
	Experiment No. 57.							
May 7	7 a. m.	54.52						
May 7–8	7 a. m. to 10 a. m	61.42	+ 6.90	+ 650.00	35.50	+ 692.40	165.46	857.86
	10 a. m. to 1 p. m	65.06	+ 3.64	+ 650.00	35.50	+ 689.14	219.87	909.01
	Total, 6 hours		+10.54	+1,300.00	71.00	+1,381.54	385.33	1,766.87

* Including the solids of perspiration. The amount of these was not determined.

Table 111.—*Record of water of respiration and perspiration, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	(*a*) Total amount of vapor in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) or loss.	(*d*) Amount in underclothes.	(*e*) Total amount gained (+) or lost (−) during period, *f*+*c*+*a*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *e*+*f*.
	Experiment No. 57—Continued.							
1903.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
May 7–8	1 p. m. to 4 p. m.	66.82	+ 1.76	+ 495.20	35.50	+ 532.46	198.90	731.36
	4 p. m. to 7 p. m.	66.99	+ .17	+ 495.20	35.50	+ 530.87	221.31	752.18
	Total, 6 hours		+ 1.93	+ 990.40	71.00	+1,063.33	420.21	1,483.54
	7 p. m. to 10 p. m.	65.12	− 1.87	+ 53.00		+ 51.13	141.25	192.38
	10 p. m. to 1 a. m.	69.75	+ 4.63	+ 53.00		+ 57.63	93.51	151.14
	Total, 6 hours		+ 2.76	+ 106.00		+ 108.76	234.76	343.52
	1 a. m. to 4 a. m.	64.32	− 5.43	+ 42.90		+ 37.47	113.66	151.13
	4 a. m. to 7 a. m.	61.27	− 3.05	+ 42.90		+ 39.85	109.85	149.70
	Total, 6 hours		− 8.48	+ 85.80		+ 77.32	223.51	300.83
	Total, 1 day		+ 6.75	+2,482.20	142.00	+2,630.95	1,263.81	3,894.76
May 8–9	7 a. m. to 10 a. m.	68.06	+ 6.79	+ 590.40	40.10	+ 637.29	119.15	756.44
	10 a. m. to 1 p. m.	68.84	+ .78	+ 590.40	40.10	+ 631.28	202.75	834.03
	Total, 6 hours		+ 7.57	+1,180.80	80.20	+1,268.57	321.90	1,590.47
	1 p. m. to 4 p. m.	65.70	− 3.14	+ 631.50	40.10	+ 668.46	203.84	872.30
	4 p. m. to 7 p. m.	68.64	+ 2.94	+ 631.50	40.00	+ 674.44	215.22	889.66
	Total, 6 hours		− .20	+1,263.00	80.10	+1,342.90	419.06	1,761.96
	7 p. m. to 10 p. m.	60.53	− 8.11	+ 19.20		+ 11.09	204.10	215.19
	10 p. m. to 1 a. m.	65.05	+ 4.52	+ 19.20		+ 23.72	192.68	216.40
	Total, 6 hours		− 3.59	+ 38.40		+ 34.81	396.78	431.59
	1 a. m. to 4 a. m.	58.93	− 6.12	+ 14.10		+ 7.98	204.08	212.06
	4 a. m. to 7 a. m.	58.35	− .58	+ 14.10		+ 13.52	181.87	195.39
	Total, 6 hours		− 6.70	+ 28.20		+ 21.50	385.95	407.45
	Total, 1 day		− 2.92	+2,510.40	160.30	+2,667.78	1,523.69	4,191.47
May 9–10	7 a. m. to 10 a. m.	64.74	+ 6.39	+ 756.10	31.00	+ 793.49	159.18	952.67
	10 a. m. to 1 p. m.	66.37	+ 1.63	+ 756.10	31.00	+ 788.73	265.90	1,054.63
	Total, 6 hours		+ 8.02	+1,512.20	62.00	+1,582.22	425.08	2,007.30
	1 p. m. to 4 p. m.	69.57	+ 3.20	+ 445.10	30.90	+ 479.20	142.51	621.71
	4 p. m. to 7 p. m.	63.96	− 5.61	+ 445.00	30.90	+ 470.29	195.81	666.10
	Total, 6 hours		− 2.41	+ 890.10	61.80	+ 949.49	338.32	1,287.81
	7 p. m. to 10 p. m.	60.56	− 3.50	+ 6.20		+ 2.70	181.94	184.64
	10 p. m. to 1 a. m.	62.68	+ 2.22	+ 6.20		+ 8.42	188.94	197.36
	Total, 6 hours		− 1.28	+ 12.40		+ 11.12	370.88	382.00
	1 a. m. to 4 a. m.	59.09	− 3.59	+ 4.30		+ .71	170.51	171.22
	4 a. m. to 7 a. m.	57.52	− 1.57	+ 4.20		+ 2.63	181.82	184.45
	Total, 6 hours		− 5.16	+ 8.50		+ 3.34	352.33	355.67
	Total, 1 day		− .83	+2,423.20	123.80	+2,546.17	1,486.61	4,032.78
	Total, 3 days		+ 3.00	+7,415.80	426.10	+7,844.90	4,274.11	12,119.01

TABLE 111.—*Record of water of respiration and perspiration, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	(*a*) Total amount of vapor in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) or loss.	(*d*) Amount in underclothes.	(*e*) Total amount gained (+) or lost (−) during period, *f*+*c*+*a*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *e*+*f*.
	Experiment No. 58.							
1903.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Nov. 10	7 a. m.	45.05						
Nov. 10–11	7 a. m. to 1 p. m.	51.66	+ 6.61			+ 6.61	116.01	122.62
	1 p. m. to 7 p. m.	49.50	− 2.16			− 2.16	113.18	111.02
	7 p. m. to 1 a. m.	48.24	− 1.26			− 1.26	130.99	129.73
	1 a. m. to 7 a. m.	50.15	+ 1.91			+ 1.91	141.85	143.76
	Total, 1 day		+ 5.10			+ 5.10	502.03	507.13
Nov. 11–12	7 a. m. to 1 p. m.	43.78	− 6.37			− 6.37	185.98	179.61
	1 p. m. to 7 p. m.	41.40	− 2.38			− 2.38	215.79	213.41
	7 p. m. to 1 a. m.	39.76	− 1.64			− 1.64	228.32	226.68
	1 a. m. to 7 a. m.	36.07	− 3.69			− 3.60	212.77	209.08
	Total, 1 day		−14.08			−14.08	842.86	828.78
Nov. 12–13	7 a. m. to 1 p. m.	34.01	− 2.06			− 2.06	216.61	214.55
	1 p. m. to 7 p. m.	36.63	+ 2.62			+ 2.62	187.50	190.12
	7 p. m. to 1 a. m.	35.52	− 1.11			− 1.11	215.22	214.11
	1 a. m. to 7 a. m.	35.38	− .14			− .14	198.30	198.16
	Total, 1 day		− .69			− .69	817.63	816.94
	Total, 3 days		− 9.67			− 9.67	2,162.52	2,152.85
	Preliminary to experiment No. 60.							
1904. Jan. 26–27	11 p. m.	33.61						
	11 p. m. to 1 a. m.	30.82	− 2.79			− 2.79	86.30	83.51
	1 a. m. to 4 a. m.	27.96	− 2.86			− 2.86	114.39	111.53
	4 a. m. to 7 a. m.	25.73	− 2.23			− 2.23	109.81	107.58
	Total, 8 hours		− 7.88			− 7.88	310.50	302.62
	Experiment No. 60.							
Jan. 27–28	7 a. m. to 10 a. m.	31.84	+ 6.11			+ 6.11	128.79	134.90
	10 a. m. to 1 p. m.	29.19	− 2.65			− 2.65	120.22	117.57
	Total, 6 hours		+ 3.46			+ 3.46	249.01	252.47
	1 p. m. to 4 p. m.	30.13	+ .94			+ .94	123.44	124.38
	4 p. m. to 7 p. m.	28.88	− 1.25			− 1.25	122.04	120.79
	Total, 6 hours		− .31			− .31	245.48	245.17
	7 p. m. to 10 p. m.	29.74	+ .86			+ .86	128.00	128.86
	10 p. m. to 1 a. m.	24.29	− 5.45			− 5.45	119.33	113.88
	Total, 6 hours		− 4.59			− 4.59	247.33	242.74
	1 a. m. to 4 a. m.	22.68	− 1.61			− 1.61	106.16	104.55
	4 a. m. to 7 a. m.	21.48	− 1.20			− 1.20	115.81	114.61
	Total, 6 hours		− 2.81			− 2.81	221.97	219.16
	Total, 1 day		− 4.25			− 4.25	963.79	959.54
Jan. 28–29	7 a. m. to 10 a. m.	45.72	+24.24			+24.24	13.28	37.52
	10 a. m. to 1 p. m.	48.83	+ 3.11			+ 3.11	13.55	16.66
	Total, 6 hours		+27.35			+27.35	26.83	54.18
	1 p. m. to 4 p. m.	51.43	+ 2.60			+ 2.60	29.46	32.06
	4 p. m. to 7 p. m.	52.70	+ 1.27			+ 1.27	44.32	45.59
	Total, 6 hours		+ 3.87			+ 3.87	73.78	77.65

Table 111.—*Record of water of respiration and perspiration, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	(*a*) Total amount of vapor in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) or loss.	(*d*) Amount in underclothes.	(*e*) Total amount gained (+) or lost (−) during period, *f*+*c*+*a*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *c*+*f*.
	Experiment No. 60—Continued.							
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Jan. 28–29..	7 p. m. to 10 p. m....	51.96	− 0.74			− 0.74	39.69	38.95
	10 p. m. to 1 a. m....	51.78	− .18			− .18	41.04	40.86
	Total, 6 hours.		− .92			− .92	80.73	79.81
	1 a. m. to 4 a. m.....	53.14	+ 1.36			+ 1.36	29.85	31.21
	4 a. m. to 7 a. m.....	55.69	+ 2.55			+ 2.55	26.75	29.30
	Total, 6 hours.		+ 3.91			+ 3.91	56.60	60.51
	Total, 1 day...		+34.21			+ 34.21	237.94	272.15
Jan. 29–30..	7 a. m. to 10 a. m....	47.72	− 7.97	+ 24.75		+ 16.78	154.28	171.06
	10 a. m. to 1 p. m....	43.47	− 4.25	+ 24.75		+ 20.50	142.12	162.62
	Total, 6 hours.		−12.22	+ 49.50		+ 37.28	296.40	333.68
	1 p. m. to 4 p. m.....	46.36	+ 2.89	+ 24.75		+ 27.64	142.20	169.84
	4 p. m. to 7 p. m.....	44.22	− 2.14	+ 24.75		+ 22.61	146.64	169.25
	Total, 6 hours.		+ .75	+ 49.50		+ 50.25	288.84	339.09
	7 p. m. to 10 p. m....	45.37	+ 1.15			+ 1.15	147.51	148.66
	10 p. m. to 1 a. m....	42.26	− 3.11			− 3.11	144.35	141.24
	Total, 6 hours.		− 1.96			− 1.96	291.86	289.90
	1 a. m. to 4 a. m.....	38.65	− 3.61			− 3.61	125.49	121.88
	4 a. m. to 7 a. m.....	37.48	− 1.17			− 1.17	115.31	114.14
	Total, 6 hours.		− 4.78			− 4.78	240.80	236.02
	Total, 1 day...		−18.21	+ 99.00		+ 80.79	1,117.90	1,198.69
	Total, 3 days..		+11.75	+ 99.00		+ 110.75	2,319.63	2,430.38
	Experiment No. 61.							
Jan. 30–31..	7 a. m. to 10 a. m....	61.49	+24.01	+ 337.70	36.70	+ 398.41	145.56	543.97
	10 a. m. to 1 p. m....	61.52	+ .03	+ 337.60	36.70	+ 374.33	182.68	557.01
	Total, 6 hours.		+24.04	+ 675.30	73.40	+ 772.74	328.24	1,100.98
	1 p. m. to 4 p. m.....	61.96	+ .44	+ 337.60	36.70	+ 374.74	190.52	565.26
	4 p. m. to 7 p. m.....	56.64	− 5.32	+ 337.60	36.70	+ 368.98	184.52	553.50
	Total, 6 hours.		− 4.88	+ 675.20	73.40	+ 743.72	375.04	1,118.76
	7 p. m. to 10 p. m....	51.98	− 4.66			− 4.66	182.48	177.82
	10 p. m. to 1 a. m....	54.53	+ 2.55			+ 2.55	162.07	164.62
	Total, 6 hours.		− 2.11			− 2.11	344.55	342.44
	1 a. m. to 4 a. m.....	49.68	− 4.85			− 4.85	164.48	159.63
	4 a. m. to 7 a. m.....	47.97	− 1.71			− 1.71	149.35	147.64
	Total, 6 hours.		− 6.56			− 6.56	313.83	307.27
	Total, 1 day...		+10.49	+1,350.50	146.80	+1,507.79	1,361.66	2,869.45
	Preliminary to experiment No. 62.							
Apr. 15–16..	7 p. m.............	45.63						
	7 p. m. to 10 p. m....	45.04	− .59			− .59	137.00	136.41
	10 p. m. to 1 a. m....	53.03	+ 7.99			+ 7.99	142.38	150.37
	1 a. m. to 4 a. m.....	48.01	− 5.02			− 5.02	143.41	138.39
	4 a. m. to 7 a. m.....	49.26	+ 1.25			+ 1.25	137.27	138.52
	Total, 12 hours.		+ 3.63			+ 3.63	560.06	563.69

Table 111.—*Record of water of respiration and perspiration, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	(*a*) Total amount of vapor in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) or loss.	(*d*) Amount in underclothes.	(*e*) Total amount gained (+) or lost (−) during period, *f*+*c*+*a*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *e*+*f*.
	Experiment No. 62.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
1904. Apr. 16–17..	7 a. m. to 10 a.m.....	65.76	+16.50	+ 502.40	28.10	+ 547.00	144.78	691.78
	10 a. m. to 1 p. m....	55.53	−10.23	+ 502.40	28.10	+ 520.27	174.26	694.53
	Total, 6 hours.		+ 6.27	+1,004.80	56.20	+1,067.27	319.04	1,386.31
	1 p. m. to 4 p. m.....	60.63	+ 5.10	+ 502.40	28.10	+ 535.60	159.80	695.40
	4 p. m. to 7 p. m.....	57.85	− 2.78	+ 502.30	28.00	+ 527.52	180.42	707.94
	Total, 6 hours.		+ 2.32	+1,004.70	56.10	+1,063.12	340.22	1,403.34
	7 p. m. to 10 p. m....	52.25	− 5.60			− 5.60	146.05	140.45
	10 p. m. to 1 a. m....	65.25	+13.00			+ 13.00	158.83	171.83
	Total, 6 hours.		+ 7.40			+ 7.40	304.88	312.28
	1 a. m. to 4 a. m.....	55.89	− 9.36			− 9.36	166.54	157.18
	4 a. m. to 7 a. m.....	55.59	− .30			− .30	157.04	156.74
	Total, 6 hours.		− 9.66			− 9.66	323.58	313.92
	Total, 1 day...		+ 6.33	+2,009.50	112.30	+2,128.13	1,287.72	3,415.85
Apr. 17–18..	7 a. m. to 10 a. m....	67.99	+12.40	+ 391.30	19.80	+ 423.50	164.18	587.68
	10 a. m. to 1 p. m....	63.05	− 4.94	+ 391.30	19.70	+ 406.06	185.40	591.46
	Total, 6 hours.		− 7.46	+ 782.60	39.50	+ 829.56	349.58	1,179.14
	1 p. m. to 4 p. m.....	62.78	− .27	+ 391.30	19.70	+ 410.73	162.97	573.70
	4 p. m. to 7 p. m.....	60.35	− 2.43	+ 391.20	93.70	+ 408.47	177.92	586.39
	Total, 6 hours.		− 2.70	+ 782.50	39.40	+ 819.20	340.89	1,160.09
	7 p. m. to 10 p. m....	56.98	− 3.37			− 3.37	155.99	152.62
	10 p. m. to 1 a. m....	61.31	+ 4.33			+ 4.33	158.07	162.40
	Total, 6 hours.		+ .96			+ .96	314.06	315.02
	1 a. m. to 4 a. m.....	54.03	− 7.28			− 7.28	151.25	143.97
	4 a. m. to 7 a. m.....	50.73	− 3.30			− 3.30	139.03	135.73
	Total, 6 hours.		−10.58			− 10.58	290.28	279.70
	Total, 1 day...		− 4.86	+1,565.10	78.90	+1,639.14	1,294.81	2,933.95
Apr. 18–19 .	7 a. m. to 10 a. m....	67.03	+16.30	+ 572.40	24.70	+ 613.40	151.22	764.62
	10 a. m. to 1 p. m....	63.44	− 3.59	+ 572.40	24.70	+ 593.51	157.90	751.41
	Total, 6 hours.		+12.71	+1,144.80	49.40	+1,206.91	309.12	1,516.03
	1 p. m. to 4 p. m.....	64.77	+ 1.33	+ 572.40	24.70	+ 598.43	154.21	752.64
	4 p. m. to 7 p. m.....	62.14	− 2.63	+ 572.30	24.70	+ 594.37	161.21	755.58
	Total, 6 hours.		− 1.30	+1,144.70	49.40	+1,192.80	315.42	1,508.22
	7 p. m. to 10 p. m....	57.23	− 4.91			− 4.91	137.38	132.47
	10 p. m. to 1 a. m....	57.74	+ .51			+ .51	140.24	140.75
	Total, 6 hours.		− 4.40			− 4.40	277.62	273.22
	1 a. m. to 4 a. m.....	58.74	+ 1.00			+ 1.00	133.26	134.26
	4 a. m. to 7 a. m.....	57.29	− 1.45			− 1.45	142.91	141.46
	Total, 6 hours.		− .45			− .45	276.17	275.72
	Total, 1 day...		+ 6.56	+2,289.50	98.80	+2,394.86	1,178.33	3,573.19
	Total, 3 days..		+ 8.03	+5,864.10	290.00	+6,162.13	3,760.86	9,922.99

Table 111.—*Record of water of respiration and perspiration, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	(*a*) Total amount of vapor in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) or loss.	(*d*) Amount in underclothes.	(*e*) Total amount gained (+) or lost (−) during period, *f*+*c*+*a*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *e*+*f*.
	Experiment No. 63.							
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 19	7 a. m.	57.29	....	....	....	....	....	....
Apr. 19–20	7 a. m. to 10 a. m.	70.91	+13.62	+ 618.10	38.10	+ 669.82	155.76	825.58
	10 a. m. to 1 p. m.	65.88	− 5.03	+ 618.00	38.00	+ 650.97	178.80	829.77
	Total, 6 hours	....	+ 8.59	+1,236.10	76.10	+1,320.79	334.56	1,655.35
	1 p. m. to 4 p. m.	63.23	− 2.65	+ 618.00	38.00	+ 653.35	173.35	826.70
	4 p. m. to 7 p. m.	60.38	− 2.85	+ 618.00	38.00	+ 653.15	180.44	833.59
	Total, 6 hours	....	− 5.50	+1,236.00	76.00	+1,306.50	353.79	1,660.29
	7 p. m. to 10 p. m.	58.16	− 2.22	....	....	− 2.22	157.43	155.21
	10 p. m. to 1 a. m.	60.12	+ 1.96	....	....	+ 1.96	161.84	163.80
	Total, 6 hours	....	− .26	....	....	− .26	319.27	319.01
	1 a. m. to 4 a. m.	58.69	− 1.43	....	....	− 1.43	159.25	157.82
	4 a. m. to 7 a. m.	61.00	+ 2.31	....	....	+ 2.31	157.91	160.22
	Total, 6 hours	....	+ .88	....	....	+ .88	317.16	318.04
	Total, 1 day	....	+ 3.71	+2,472.10	152.10	2,627.91	1,324.78	3,952.69
Apr. 20–21	7 a. m. to 10 a. m.	71.63	+10.63	+ 495.00	45.70	+ 551.33	168.08	719.41
	10 a. m. to 1 p. m.	63.16	− 8.47	+ 495.00	45.70	+ 532.23	172.83	705.06
	Total, 6 hours	....	+ 2.16	+ 990.00	91.40	+1,083.56	340.91	1,424.47
	1 p. m. to 4 p. m.	63.24	+ .08	+ 495.00	45.70	+ 540.78	173.74	714.52
	4 p. m. to 7 p. m.	62.14	− 1.10	+ 494.90	45.60	+ 539.40	174.37	713.77
	Total, 6 hours	....	− 1.02	+ 989.90	91.30	+1,080.18	348.11	1,428.29
	7 p. m. to 10 p. m.	57.57	− 4.57	....	....	− 4.57	160.36	155.79
	10 p. m. to 1 a. m.	61.36	+ 3.79	....	....	+ 3.79	158.27	162.06
	Total, 6 hours	....	− .78	....	....	− .78	318.63	317.85
	1 a. m. to 4 a. m.	55.51	− 5.85	....	....	− 5.85	159.31	153.46
	4 a. m. to 7 a. m.	62.65	+ 7.14	....	....	+ 7.14	147.82	154.96
	Total, 6 hours	....	+ 1.29	....	....	+ 1.29	307.13	308.42
	Total, 1 day	....	+ 1.65	+1,979.90	182.70	+2,164.25	1,314.78	3,479.03
Apr. 21–22	7 a. m. to 10 a. m.	70.14	+ 7.49	+ 541.90	44.50	+ 593.89	168.28	762.17
	10 a. m. to 1 p. m.	65.42	− 4.72	+ 541.90	44.50	+ 581.68	177.44	759.12
	Total, 6 hours	....	+ 2.77	+1,083.80	89.00	+1,175.57	345.72	1,521.29
	1 p. m. to 4 p. m.	65.68	+ .26	+ 541.80	44.50	+ 586.56	186.11	772.67
	4 p. m. to 7 p. m.	61.29	− 4.39	+ 541.80	44.50	+ 581.91	179.30	761.21
	Total, 6 hours	....	− 4.13	+1,083.60	89.00	+1,168.47	365.41	1,533.88
	7 p. m. to 10 p. m.	56.80	− 4.49	....	....	− 4.49	162.48	157.99
	10 p. m. to 1 a. m.	61.23	+ 4.43	....	....	+ 4.43	159.46	163.89
	Total, 6 hours	....	− .06	....	....	− .06	321.94	321.88
	1 a. m. to 4 a. m.	55.77	− 5.46	....	....	− 5.46	134.11	128.65
	4 a. m. to 7 a. m.	52.44	− 3.33	....	....	− 3.33	151.59	148.26
	Total, 6 hours	....	− 8.79	....	....	− 8.79	285.70	276.91
	Total, 1 day	....	−10.21	+2,167.40	178.00	+2,335.19	1,318.77	3,653.96
	Total, 3 days	....	− 4.85	+6,619.40	512.80	+7,127.35	3,958.33	11,085.68

Table 111.—*Record of water of respiration and perspiration, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	(*a*) Total amount of vapor in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) or loss.	(*d*) Amount in underclothes.	(*e*) Total amount gained (+) or lost (−) during period, *f*+*c*+*a*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *e*+*f*.
	Experiment No. 64.							
1904.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Apr. 22–23.	7 a. m. to 10 a. m	70.03	+17.59	+ 622.80	13.20	+ 653.59	176.64	830.23
	10 a. m. to 1 p. m	66.77	− 3.26	+ 622.80	13.20	+ 632.74	183.28	816.02
	Total, 6 hours	....	+14.33	+1,245.60	26.40	+1,286.33	359.92	1,646.25
	1 p. m. to 4 p. m	60.55	+ 2.78	+ 622.80	13.20	+ 638.78	189.92	828.70
	4 p. m. to 7 p. m	63.77	− 5.78	+ 622.80	13.20	+ 630.22	186.69	816.91
	Total, 6 hours	....	− 3.00	+1,245.60	26.40	+1,269.00	376.61	1,645.61
	7 p. m. to 10 p. m	71.49	+ 7.72	+ 622.80	13.20	+ 643.72	194.76	838.48
	10 p. m. to 1 a. m	65.53	− 5.96	+ 622.80	13.10	+ 629.94	196.38	826.32
	Total, 6 hours	....	+ 1.76	+1,245.60	26.30	+1,273.66	391.14	1,664.80
	1 a. m. to 4 a. m	61.40	− 4.13	+ 622.80	13.10	+ 631.77	185.14	816.91
	4 a. m. to 7 a. m	60.39	− 1.01	....	....	− 1.01	167.11	166.10
	Total, 6 hours	....	− 5.14	+ 622.80	13.10	+ 630.76	352.25	983.01
	Total, 1 day	....	+ 7.95	+4,359.60	92.20	+4,459.75	1,479.92	5,939.67
	Experiment No. 65.							
Apr. 23–24.	7 a. m. to 10 a. m	63.03	+ 2.64	− 19.90	....	− 17.26	159.91	142.65
	10 a. m. to 1 p. m	55.92	− 7.11	− 19.90	....	− 27.01	157.21	130.20
	Total, 6 hours	....	− 4.47	− 39.80	....	− 44.27	317.12	272.85
	1 p. m. to 4 p. m	60.23	+ 4.31	− 19.90	....	− 15.59	152.40	136.81
	4 p. m. to 7 p. m	54.74	− 5.49	− 19.90	....	− 25.39	153.40	128.01
	Total, 6 hours	....	− 1.18	− 39.80	....	− 40.98	305.80	264.82
	7 p. m. to 10 p. m	55.10	+ .36	− 19.90	....	− 19.54	160.30	140.76
	10 p. m. to 1 p. m	58.82	+ 3.72	− 19.90	....	− 16.18	158.66	142.48
	Total, 6 hours	....	+ 4.08	− 39.80	....	− 35.72	318.96	283.24
	1 a. m. to 4 a. m	56.55	− 2.27	− 19.80	....	− 22.07	152.18	130.11
	4 a. m. to 7 a. m	51.66	− 4.89	− 19.80	....	− 24.69	146.13	121.44
	Total, 6 hours	....	− 7.16	− 39.60	....	− 46.76	298.31	251.55
	Total, 1 day	....	− 8.73	− 159.00	....	− 167.73	1,240.19	1,072.46
	Experiment No. 66.							
Apr. 25–26.	7 a. m. to 10 a. m	52.46	+ .80	− 22.10	....	− 21.30	149.80	128.50
	10 a. m. to 1 p. m	50.71	− 1.75	− 22.10	....	− 23.85	141.60	117.75
	Total, 6 hours	....	− .95	− 44.20	....	− 45.15	291.40	246.25
	1 p. m. to 4 p. m	47.48	− 3.23	− 22.10	....	− 25.33	129.34	104.01
	4 p. m. to 7 p. m	46.99	− .49	− 22.10	....	− 22.59	128.48	105.89
	Total, 6 hours	....	− 3.72	− 44.20	....	− 47.92	257.82	209.90
	7 p. m. to 10 p. m	47.46	+ .47	− 22.10	....	− 21.63	127.71	106.08
	10 p. m. to 1 a. m	47.52	+ .06	− 22.10	....	− 22.04	131.80	109.76
	Total, 6 hours	....	+ .53	− 44.20	....	− 43.67	259.51	215.84
	1 a. m. to 4 a. m	48.44	+ .92	− 22.10	....	− 21.18	133.91	112.73
	4 a. m. to 7 a. m	46.14	− 2.30	− 22.10	....	− 24.40	123.51	99.11
	Total, 6 hours	....	− 1.38	− 44.20	....	− 45.58	257.42	211.84
	Total, 1 day	....	− 5.52	− 176.80	....	− 182.32	1,066.15	883.83

Table 111.—*Record of water of respiration and perspiration, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	(*a*) Total amount of vapor in chamber at end of period.	(*b*) Gain (+) or loss (−) over preceding period.	(*c*) Change in weight of absorbers, gain (+) or loss.	(*d*) Amount in underclothes.	(*e*) Total amount gained (+) or lost (−) during period, *f*+*c*+*a*.	(*f*) Total amount in outgoing air.	(*g*) Total water of respiration and perspiration, *e*+*f*.
	Experiment No. 67.							
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
1904. Apr. 26–27.	7 a. m. to 10 a. m....	49.59	+ 3.45	− 14.50	....	− 11.05	120.44	109.39
	10 a. m. to 1 p. m....	50.39	+ .80	− 14.50	....	− 13.70	120.73	107.03
	Total, 6 hours.	....	+ 4.25	− 29.00	....	− 24.75	241.17	216.42
	1 p. m. to 4 p. m.....	50.40	+ .01	− 14.50	....	− 14.49	117.72	103.23
	4 p. m. to 7 p. m.....	48.31	− 2.09	− 14.50	....	− 16.59	123.23	106.64
	Total, 6 hours.	....	− 2.08	− 29.00	....	− 31.08	240.95	209.87
	7 p. m. to 10 p. m....	44.70	− 3.61	− 14.50	....	− 18.11	117.85	99.74
	10 p. m. to 1 a. m....	49.52	+ 4.82	− 14.50	....	− 9.68	123.14	113.46
	Total, 6 hours.	....	+ 1.21	− 29.00	....	− 27.79	240.99	213.20
	1 a. m. to 4 a. m.....	48.25	− 1.27	− 14.50	....	− 15.77	123.62	107.85
	4 a. m. to 7 a. m.....	45.48	− 2.77	− 14.50	....	− 17.27	112.21	94.94
	Total, 6 hours.	....	− 4.04	− 29.00	....	− 33.04	235.83	202.79
	Total, 1 day...	....	− .66	−116.00	....	−116.66	958.94	842.28
	7 a. m. to 10 a. m....	47.56	+ 2.08	− 4.40	....	− 2.32	116.43	114.11
	10 a. m. to 1 p. m....	47.73	+ .17	− 4.40	....	− 4.23	118.96	114.73
	Total, 6 hours.	....	+ 2.25	− 8.80	....	− 6.55	235.39	228.84
	1 p. m. to 4 p. m.....	51.22	+ 3.49	− 4.40	....	− .91	116.92	116.01
	4 p. m. to 7 p. m.....	46.20	− 5.02	− 4.40	....	− 9.42	118.17	108.75
	Total, 6 hours.	....	− 1.53	− 8.80	....	− 10.33	235.09	224.76
	7 p. m. to 10 p. m...	46.87	+ .67	− 4.40	....	− 3.73	111.09	107.36
	10 p. m. to 1 a. m....	47.95	+ 1.08	− 4.40	....	− 3.32	115.13	111.81
	Total, 6 hours.	....	+ 1.75	− 8.80	....	− 7.05	226.22	219.17
	1 a. m. to 4 a. m.....	47.21	− .74	− 4.30	....	− 5.04	111.90	106.86
	4 a. m. to 7 a. m.....	44.64	− 2.57	− 4.30	....	− 6.87	105.00	98.13
	Total, 6 hours.	....	− 3.31	− 8.60	....	− 11.91	216.90	204.99
	Total, 1 day...	....	− .84	− 35.00	....	− 35.84	913.60	877.76
	Total, 2 days..	....	− 1.50	−151.00	....	−152.50	1,872.54	1,720.04

TABLE 112.—*Water eliminated from the lungs and skin by 3-hour periods, metabolism experiments Nos. 56–58 and 60–67.*

Kind and number of experiment.	Day.	7 a. m. to 10 a. m.	10 a. m. to 1 p. m.	Total, 6 hours.	1 p. m. to 4 p. m.	4 p. m. to 7 p. m.	Total, 6 hours.	7 p. m. to 10 p. m.	10 p. m. to 1 a. m.	Total, 6 hours.	1 a. m. to 4 a. m.	4 a. m. to 7 a. m.	Total, 6 hours.	Total, 1 day.
Rest experiments, carbohydrate diet.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 58[a]	1			122.62			111.02			129.73			143.76	507.13
No. 58	2			179.61			213.41			226.68			209.08	828.78
No. 58	3			214.55			190.12			214.11			198.16	816.94
Average per day				172.26			171.52			190.17			183.67	717.62
No. 60	1	134.90	117.57	252.47	124.38	120.79	245.17	128.86	113.88	242.74	104.55	114.61	219.16	959.54
No. 60	2	37.52	16.66	54.18	32.06	45.59	77.65	38.95	40.86	79.81	31.21	29.30	60.51	272.15
No. 60	3	171.06	162.62	333.68	169.84	169.25	339.09	148.66	141.24	289.90	121.88	114.14	236.02	1,198.69
Average per day		114.49	98.95	213.44	108.76	111.88	220.64	105.49	98.66	204.15	85.88	86.02	171.90	810.13
No. 65	1	142.65	130.20	272.85	136.81	128.01	264.82	140.76	142.48	283.24	130.11	121.44	251.55	1,072.46
No. 66	1	128.50	117.75	246.25	104.01	105.89	209.90	106.08	109.76	215.84	112.73	99.11	211.84	883.83
No. 67	1	109.39	107.03	216.42	103.23	106.64	209.87	99.74	113.46	213.20	107.85	94.94	202.79	842.28
No. 67	2	114.11	114.73	228.84	116.01	108.75	224.76	107.36	111.81	219.17	106.86	98.13	204.99	877.76
Average per day		111.75	110.88	222.63	109.62	107.70	217.32	103.55	112.63	216.18	107.36	96.53	203.89	860.02
Average, Nos. 65, 66, 67		123.66	117.43	241.09	115.02	112.32	227.34	113.49	119.37	232.86	114.39	103.40	217.79	919.08
Average, Nos. 58, 60, 65, 66, 67		[b]119.73	[b]109.51	212.15	[b]112.34	[b]112.13	208.58	[b]110.06	[b]110.48	211.44	[b]102.17	[b]95.95	193.79	825.96
Work experiments, carbohydrate diet.														
No. 57	1	857.86	909.01	1,766.87	731.36	752.18	1,483.54	192.38	151.14	343.52	151.13	149.70	300.83	3,894.76
No. 57	2	756.44	834.03	1,590.47	872.30	889.66	1,761.96	215.19	216.40	431.59	212.06	195.39	407.45	4,191.47
No. 57	3	952.67	1,054.63	2,007.30	621.71	666.10	1,287.81	184.64	197.36	382.00	171.22	184.45	355.67	4,032.78
Average per day		855.66	932.56	1,788.22	741.79	769.31	1,511.10	197.40	188.30	385.70	178.14	176.51	354.65	4,039.67
No. 61	1	543.97	557.01	1,100.98	565.26	553.50	1,118.76	177.82	164.62	342.44	159.63	147.64	307.27	2,869.45
No. 62	1	691.78	694.53	1,386.31	695.40	707.94	1,403.34	140.45	171.83	312.28	157.18	156.74	313.92	3,415.85
No. 62	2	587.68	591.46	1,179.14	573.70	586.39	1,160.09	152.62	162.40	315.02	143.97	135.73	279.70	2,933.95
No. 62	3	764.62	751.41	1,516.03	752.64	755.58	1,508.22	132.47	140.75	273.22	134.26	141.46	275.72	3,573.19
Average per day		681.36	679.13	1,360.49	673.91	683.30	1,357.21	141.85	158.33	300.18	145.14	144.64	289.78	3,307.66
Average, Nos. 57, 61, 62		736.43	770.30	1,506.73	687.48	701.62	1,389.10	170.80	172.07	342.87	161.35	158.73	320.08	3,558.78

Work experiments, fat diet.														
No. 56 [c]	1	....	....	1,342.35	....	....	1,553.48	....	....	418.03	....	....	388.41	3,702.27
No. 56	2	887.24	884.17	1,771.41	833.64	831.39	1,665.03	188.05	189.18	377.23	191.81	174.30	366.11	4,179.78
No. 56	3	740.51	745.48	1,485.99	849.46	850.37	1,699.83	178.06	191.53	369.59	179.90	171.83	351.73	3,907.14
Average per day	......	[d]813.88	[d]814.82	1,533.25	[d]841.55	[d]840.88	1,639.45	[d]183.06	[d]190.35	388.28	[d]185.86	[d]173.06	368.75	3,929.73
No. 63	1	825.58	829.77	1,655.35	826.70	833.59	1,660.29	155.21	163.80	319.01	157.82	160.22	318.04	3,952.69
No. 63	2	719.41	705.06	1,424.47	714.52	713.77	1,428.29	155.79	162.06	317.85	153.46	154.96	308.42	3,479.03
No. 63	3	762.17	759.12	1,521.29	772.67	761.21	1,533.88	157.99	163.89	321.88	128.65	148.26	276.91	3,653.96
Average per day	......	769.05	764.65	1,533.70	771.30	769.52	1,540.82	156.33	163.25	319.58	146.64	154.48	301.12	3,695.22
Average, Nos. 56, 63	......	[e]786.98	[e]784.72	1,533.48	[e]799.40	[e]798.06	1,590.13	[e]167.02	[e]174.09	353.93	[e]162.33	[e]161.91	334.94	3,812.48
Average, Nos. 56, 57, 61, 62, 63	......	[e]757.49	[e]776.31	1,519.08	[e]734.11	[e]741.80	1,481.88	[e]169.23	[e]172.91	347.97	[e]161.76	[e]160.06	326.94	3,675.87
Severe work, fat diet.														
No. 64	1	830.23	816.02	1,646.25	828.70	816.91	1,645.61	838.48	826.32	1,664.80	816.91	166.10	983.01	5,939.67
Average, Nos. 56, 57, 61, 62, 63, 64	......	[e]763.09	[e]779.36	1,528.16	[e]741.39	[e]747.58	1,493.58	[e]220.71	[e]223.17	[e]442.03	[e]212.16	[e]160.52	373.80	3,837.57
Average all experiments	......	[f]537.92	[f]544.91	979.82	[f]521.22	[f]525.17	958.16	[f]181.98	[f]183.73	345.95	[f]173.66	[f]137.92	298.80	2,582.73

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[a] In No. 58 records were made only by 6-hour periods.

[b] Average of Nos. 60, 65, 66, and 67.

[c] During the first day of No. 56 records were made only by 6-hour periods.

[d] Average of second and third days.

[e] First day of No. 56 not included in 3-hour averages.

[f] No. 58 and first day of No. 56 not included in 3-hour averages.

TABLE 113.—*Daily income and outgo of water, metabolism experiments Nos. 56–58 and 60–67.*

Number, subject, and kind of experiment.	Duration.	Income.			Outgo.			
		In food.	In drink.	Total.	In feces.	In urine.	In respiration and perspiration.	Total.
Rest experiments.								
No. 58, with H. F., carbohydrate diet:	*Days.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
First day	3	558.50	400.00	958.50	34.77	372.90	507.13	914.80
Second day		536.80	400.00	936.80	34.77	366.90	828.78	1,230.45
Third day		619.30	263.00	882.30	34.77	410.00	816.94	1,261.71
Total	......	1,714.60	1,063.00	2,777.60	104.31	1,149.80	2,152.85	3,406.96
No. 60, with B. F. D., carbohydrate diet:								
First day	3	1,159.30	700.00	1,859.30	97.07	1,046.32	959.54	2,102.93
Second day		1,054.80	700.00	1,754.80	97.07	951.30	272.15	1,320.52
Third day		1,054.80	700.00	1,754.80	97.07	1,298.88	1,198.69	2,594.64
Total	......	3,268.90	2,100.00	5,368.90	291.21	3,296.50	2,430.38	6,018.09
No. 65, with A. L. L., carbohydrate diet	1	2,255.51	....	2,255.51	62.17	1,020.64	1,072.46	2,155.27
No. 66, with A. L. L., carbohydrate diet	1	2,039.22	....	2,039.22	62.17	981.18	883.83	1,927.18
No. 67, with A. L. L., carbohydrate diet:								
First day	2	1,581.24	....	1,581.24	62.17	1,013.77	842.28	1,918.22
Second day		1,405.02	....	1,405.02	62.17	1,266.29	877.76	2,206.22
Total	......	2,986.26	....	2,986.26	124.34	2,280.06	1,720.04	4,124.44
Work experiments.								
No. 56, with J. C. W., fat diet:								
First day	3	2,935.50	1,950.00	4,885.50	191.30	1,425.80	3,702.27	5,319.37
Second day		2,970.10	1,950.00	4,920.10	191.30	927.50	4,179.78	5,298.58
Third day		3,011.70	1,950.00	4,961.70	191.30	914.30	3,907.14	5,012.74
Total	......	8,917.30	5,850.00	14,767.30	573.90	3,267.60	11,789.19	15,630.69
No. 57, with J. C. W., carbohydrate diet:								
First day	3	2,310.10	2,291.00	4,601.10	298.53	932.21	3,894.76	5,125.50
Second day		2,394.70	2,291.00	4,685.70	298.53	789.10	4,191.47	5,279.10
Third day		2,394.70	2,291.00	4,685.70	298.53	806.53	4,032.78	5,137.84
Total	......	7,099.50	6,873.00	13,972.50	895.59	2,527.84	12,119.01	15,542.44
No 61, with B. F. D., carbohydrate diet	1	1,029.50	1,834.00	2,863.50	92.67	843.00	2,869.45	3,805.12
No. 62, with A. L. L., carbohydrate diet:								
First day	3	779.40	2,797.90	3,577.30	151.60	490.50	3,415.85	4,057.95
Second day		674.10	2,879.10	3,553.20	151.60	494.30	2,933.95	3,579.85
Third day		591.10	2,900.00	3,491.10	151.60	626.70	3,573.19	4,351.49
Total	......	2,044.60	8,577.00	10,621.60	454.80	1,611.50	9,922.99	11,989.29
No. 63, with A. L. L., fat diet:								
First day	3	629.50	2,478.60	3,108.10	97.15	913.45	3,952.69	4,963.29
Second day		1,949.60	2,200.70	4,150.30	97.15	1,758.86	3,479.03	5,335.04
Third day		2,420.10	1,731.80	4,151.90	97.15	1,757.04	3,653.96	5,508.15
Total	......	4,999.20	6,411.10	11,410.30	291.45	4,429.35	11,085.68	15,806.48
No. 64, with A. L. L., fat diet, severe work	1	2,897.50	3,832.00	6,729.50	97.15	1,075.55	5,939.67	7,112.37

TABLE 114.—*Record of oxygen in ventilating air current and respiratory quotient, metabolism experiments Nos. 56–58 and 60–67.*

Date.	Period.	Oxygen.					(*f*) Volume of oxygen consumed, $e \times 0.7$.	(*g*) Volume of carbon dioxid exhaled.	(*h*) Respiratory quotient, $g \div f$.
		(*a*) Total amount in chamber at end of period.	Gain (+) or loss (−) over preceding period.		(*d*) Amount admitted to chamber.	(*e*) Corrected amounts consumed by subject, $d - c$.			
			(*b*) Volume.	(*c*) Weight, $b \div 0.7$.					
	Preliminary to experiment No. 56.								
1903.		*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Apr. 27	1 a. m.	976.40	....	....	....	....	....	....	....
	1 a. m. to 7 a. m.	972.14	− 4.26	− 6.09	135.35	141.44	99.0	83.4	0.8424
	Experiment No. 56.								
Apr. 27–28	7 a. m. to 1 p. m.	882.19	− 89.95	−128.50	455.89	584.39	409.1	353.2	.8636
	1 p. m. to 7 p. m.	897.66	+ 15.47	+ 22.10	624.70	602.60	421.8	346.6	.8217
	7 p. m. to 1 a. m.	944.69	+ 47.03	+ 67.19	271.73	204.54	143.2	121.1	.8460
	1 a. m. to 7 a. m.	967.44	+ 22.75	+ 32.50	186.21	153.71	107.6	83.1	.7723
	Total, 1 day	....	− 4.70	− 6.71	1,538.53	1,545.24	1,081.7	904.0	.8357
Apr. 28–29	7 a. m. to 10 a. m.	867.83	− 99.61	−142.30	199.83	342.13	239.5	174.9	.7303
	10 a. m. to 1 p. m.	868.70	+ .87	+ 1.24	361.39	360.15	252.1	209.1	.8294
	Total, 6 hours	....	− 98.74	−141.06	561.22	702.28	491.6	384.0	.7811
	1 p. m. to 4 p. m.	836.01	− 32.69	− 46.70	285.94	332.64	232.8	183.6	.7887
	4 p. m. to 7 p. m.	887.94	+ 51.93	+ 74.19	326.06	251.87	176.3	149.5	.8480
	Total, 6 hours	....	+ 19.24	+ 27.49	612.00	584.51	409.1	333.1	.8142
	7 p. m. to 10 p. m.	900.32	+ 12.38	+ 17.69	139.91	122.22	85.6	69.3	.8096
	10 p. m. to 1 a. m.	891.78	− 8.54	− 12.20	79.73	91.93	64.4	52.7	.8183
	Total, 6 hours	....	+ 3.84	+ 5.49	219.64	214.15	150.0	122.0	.8133
	1 a. m. to 4 a. m.	904.87	+ 13.09	+ 18.70	99.59	80.89	56.6	44.4	.7845
	4 a. m. to 7 a. m.	936.17	+ 31.30	+ 44.71	115.44	70.73	49.5	39.9	.8061
	Total, 6 hours	....	+ 44.39	+ 63.41	215.03	151.62	106.1	84.3	.7945
	Total, 1 day	....	− 31.27	− 44.67	1,607.89	1,652.56	1,156.8	923.4	.7983
Apr. 29–30	7 a. m. to 10 a. m.	862.28	− 73.89	−105.56	195.95	301.51	211.1	175.2	.8299
	10 a. m. to 1 p. m.	874.62	+ 12.34	+ 17.63	268.51	250.88	175.6	139.6	.7950
	Total, 6 hours	....	− 61.55	− 87.93	464.46	552.39	386.7	314.8	.8141
	1 p. m. to 4 p. m.	810.61	− 64.01	− 91.44	222.34	313.78	219.6	187.4	.8534
	4 p. m. to 7 p. m.	835.47	+ 24.86	+ 35.51	324.50	288.99	202.3	160.8	.7949
	Total, 6 hours	....	− 39.15	− 55.93	546.84	602.77	421.9	348.2	.8253
	7 p. m. to 10 p. m.	872.72	+ 37.25	+ 53.21	163.33	110.12	77.1	66.0	.8560
	10 p. m. to 1 a. m.	851.41	− 21.31	− 30.44	75.64	106.08	74.3	52.5	.7066
	Total, 6 hours	....	+ 15.94	+ 22.77	238.97	216.20	151.4	118.5	.7827
	1 a. m. to 4 a. m.	854.54	+ 3.13	+ 4.47	86.10	81.63	57.1	45.0	.7881
	4 a. m. to 7 a. m.	871.62	+ 17.08	+ 24.40	89.21	64.81	45.4	37.7	.8305
	Total, 6 hours	....	+ 20.21	+ 28.87	175.31	146.44	102.5	82.7	.8068
	Total, 1 day	....	− 64.55	− 92.22	1,425.58	1,517.80	1,062.5	864.2	.8134
	Total, 3 days	....	−100.52	−143.60	4,572.00	4,715.60	3,301.0	2,691.6	.8154
	Experiment No. 57.								
May 7	7 a. m.	1,025.26	....	....	....	....	....	....	....
May 7–8	7 a. m. to 10 a. m.	956.54	− 68.72	− 98.17	192.48	290.65	203.50	197.00	.9681
	10 a. m. to 1 p. m.	938.19	− 18.35	− 26.21	329.65	355.86	249.10	237.00	.9511
	Total, 6 hours	....	− 87.07	−124.38	522.13	646.51	452.60	434.00	.9589

Table 114.—*Record of oxygen in ventilating air current and respiratory quotient, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Oxygen.					(*f*) Volume of oxygen consumed, *e*×0.7.	(*g*) Volume of carbon dioxid exhaled.	(*h*) Respiratory quotient, *g*÷*f*.
		(*a*) Total amount in chamber at end of period.	Gain (+) or loss (−) over preceding period. (*b*) Volume.	(*c*) Weight, *b*÷0.7.	(*d*) Amount admitted to chamber.	(*e*) Corrected amounts consumed by subject, *d*−*c*.			
	Experiment No. 57—Continued.								
1903.		*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
May 7–8....	1 p. m. to 4 p. m....	901.94	− 36.25	− 51.78	234.38	286.16	200.30	174.40	0.8707
	4 p. m. to 7 p. m....	925.37	+ 23.43	+ 33.47	355.66	322.19	225.50	223.50	.9911
	Total, 6 hours	....	− 12.82	− 18.31	590.04	608.35	425.80	397.90	.9345
	7 p. m. to 10 p. m ..	944.73	+ 19.36	+ 27.66	141.54	113.88	79.70	84.10	1.0552
	10 p. m. to 1 a. m ..	936.29	− 8.44	− 12.06	76.66	88.72	62.10	59.00	.9501
	Total, 6 hours	....	− 10.92	+ 15.60	218.20	202.60	141.80	143.10	1.0090
	1 a. m. to 4 a. m....	948.48	+ 12.19	+ 17.41	106.61	89.20	62.40	44.60	.7147
	4 a. m. to 7 a. m....	990.95	+ 42.47	+ 60.67	122.77	62.10	43.50	45.90	1.0554
	Total, 6 hours	....	+ 54.66	+ 78.07	229.38	151.30	105.90	90.50	.8546
	Total, 1 day..	....	− 34.31	− 49.01	1,559.75	1,608.76	1,126.10	1,065.50	.9462
May 8–9....	7 a. m. to 10 a. m ..	899.75	− 91.20	−130.29	111.22	241.51	169.10	168.70	.9982
	10 a. m. to 1 p. m ..	917.88	+ 18.13	+ 25.90	317.76	291.86	204.30	199.50	.9770
	Total, 6 hours	....	− 73.07	−104.39	428.98	533.37	373.40	368.20	.9861
	1 p. m. to 4 p. m ...	886.64	− 31.24	− 44.64	208.19	252.83	177.00	184.50	1.0424
	4 p. m. to 7 p. m ...	891.48	+ 4.84	+ 6.92	342.55	335.63	234.90	215.00	.9153
	Total, 6 hours	....	− 26.40	− 37.72	550.74	588.46	411.90	399.50	.9699
	7 p. m. to 10 p. m ..	921.74	+ 30.26	+ 43.23	166.55	123.32	86.30	84.80	.9826
	10 p. m. to 1 a. m ..	928.95	+ 7.21	+ 10.30	98.13	87.83	61.50	71.10	1.1560
	Total, 6 hours	....	+ 37.47	+ 53.53	264.68	211.15	147.80	155.90	1.0548
	1 a. m. to 4 a. m....	889.66	− 39.29	− 56.13	104.45	160.58	112.40	43.10	.3835
	4 a. m. to 7 a. m....	923.22	+ 33.56	+ 47.95	117.22	69.27	48.50	45.80	.9443
	Total, 6 hours	....	− 5.73	− 8.18	221.67	229.85	160.90	88.90	.5525
	Total, 1 day..	....	− 67.73	− 96.76	1,466.07	1,562.83	1,094.00	1,012.50	.9256
May 9–10...	7 a. m. to 10 a. m ..	820.92	−102.30	−146.15	154.67	300.82	210.60	212.90	1.0114
	10 a. m. to 1 p. m ..	810.42	− 10.50	− 15.00	395.63	410.63	287.40	249.90	.8695
	Total, 6 hours	....	−112.80	−161.15	550.30	711.45	498.00	462.80	.9293
	1 p. m. to 4 p. m ...	779.65	− 30.77	− 43.96	311.98	355.94	249.20	202.20	.8114
	4 p. m. to 7 p. m ...	863.68	+ 84.03	+120.04	280.22	160.18	112.10	102.60	.9153
	Total, 6 hours	....	+ 53.26	+ 76.08	592.20	516.12	361.30	304.80	.8436
	7 p. m. to 10 p. m ..	868.71	+ 5.03	+ 7.19	114.09	106.90	74.80	84.70	1.1323
	10 p. m. to 1 a. m ..	864.26	− 4.45	− 6.36	79.37	85.73	60.00	53.40	.8900
	Total, 6 hours	....	+ .58	+ .83	193.46	192.63	134.80	138.10	1.0245
	1 a. m. to 4 a. m....	870.03	+ 5.77	+ 8.25	74.73	66.48	46.60	43.90	.9421
	4 a. m. to 7 a. m....	878.28	+ 8.25	+ 11.79	81.90	70.11	49.10	44.70	.9104
	Total, 6 hours	....	+ 14.02	+ 20.04	156.63	136.59	95.70	88.60	.9258
	Total, 1 day..	....	− 44.94	− 64.20	1,492.59	1,556.79	1,089.80	994.30	.9124
	Total, 3 days.	....	−146.98	−209.97	4,578.41	4,728.38	3,309.90	3,072.30	.9282

Table 114.—*Record of oxygen in ventilating air current and respiratory quotient, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Oxygen.					(*f*)	(*g*)	(*h*)
		(*a*) Total amount in chamber at end of period.	Gain (+) or loss (−) over preceding period.		(*d*) Amount admitted to chamber.	(*e*) Corrected amounts consumed by subject, $d - c$.	Volume of oxygen consumed, $e \times 0.7$.	Volume of carbon dioxid exhaled.	Respiratory quotient, $g \div f$.
			(*b*) Volume.	(*c*) Weight, $b \div 0.7$.					
	Preliminary to experiment No. 58.								
1903.		*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Nov. 10	1 a.m.	931.20	....	....	....	....	....	....	....
	1 a.m. to 7 a.m.	885.37	−45.82	− 65.47	45.34	110.83	77.58	59.99	0.7733
	Experiment No. 58.								
Nov. 10–11	7 a.m. to 1 p.m.	854.92	−30.45	− 43.50	78.20	121.70	85.19	67.60	.7935
	1 p.m. to 7 p.m.	845.98	− 8.94	− 12.77	137.66	150.43	105.30	95.23	.9044
	7 p.m. to 1 a.m.	849.12	+ 3.14	+ 4.49	142.74	138.25	96.78	85.72	.8856
	1 a.m. to 7 a.m.	853.41	+ 4.29	+ 6.13	124.25	118.12	82.68	71.21	.8612
	Total, 1 day	....	−31.96	− 45.65	482.85	528.50	369.95	319.76	.8643
Nov. 11–12	7 a.m. to 1 p.m.	865.23	+11.82	+ 16.89	172.46	155.57	108.90	81.73	.7505
	1 p.m. to 7 p.m.	874.64	+ 9.41	+ 13.44	148.86	135.42	94.79	91.37	.9641
	7 p.m. to 1 a.m.	846.24	−28.40	− 40.57	97.84	138.41	96.89	85.53	.8827
	1 a.m. to 7 a.m.	876.07	+29.83	+ 42.61	162.19	119.58	83.71	69.51	.8304
	Total, 1 day	....	+22.66	+ 32.37	581.35	548.98	384.29	328.14	.8539
Nov. 12–13	7 a.m. to 1 p.m.	853.59	−22.48	− 32.11	125.12	157.23	110.06	93.75	.8518
	1 p.m. to 7 p.m.	881.26	+27.67	+ 39.53	196.12	156.59	109.61	105.08	.9467
	7 p.m. to 1 a.m.	850.74	−30.52	− 43.60	103.11	146.71	102.70	87.33	.8506
	1 a.m. to 7 a.m.	859.56	+ 8.82	+ 12.60	141.20	128.60	90.02	73.40	.8154
	Total, 1 day	....	−16.51	− 23.58	565.55	589.13	412.39	359.56	.8719
	Total, 3 days.	....	−25.81	− 36.86	1,629.75	1,666.61	1,166.63	1,007.46	.8635
	Preliminary to experiment No. 60.								
1904. Jan. 26–27	11 p.m.	962.12	....	....	....	....	....	....	....
	11 p.m. to 1 a.m.	962.47	+ .35	+ .50	34.71	34.21	23.95	22.58	.9428
	1 a.m. to 4 a.m.	976.46	+13.99	+ 20.00	72.77	52.77	36.94	30.65	.8297
	4 a.m. to 7 a.m.	992.78	+16.32	+ 23.31	77.43	54.12	37.88	31.43	.8297
	Total, 8 hours.	....	+30.66	+ 43.81	184.91	141.10	98.77	84.66	.8572
	Experiment No. 60.								
Jan. 27	7 a. m.	985.41	....	....	....	....	....	....	....
Jan. 27–28	7 a. m. to 10 a. m.	991.54	+ 6.13	+ 8.76	119.18	110.42	77.29	64.54	.8350
	10 a. m. to 1. p. m.	997.77	+ 6.23	+ 8.90	82.52	73.62	51.53	49.63	.9631
	Total, 6 hours	....	+12.36	+ 17.66	201.70	184.04	128.82	114.17	.8862
	1 p. m. to 4 p. m.	1,006.99	+ 9.22	+ 13.17	101.50	88.33	61.83	54.45	.8805
	4 p. m. to 7 p. m.	1,019.43	+12.44	+ 17.77	94.56	76.79	53.75	50.26	.9351
	Total, 6 hours	....	+21.66	+ 30.94	196.06	165.12	115.58	104.71	.9060
	7 p. m. to 10 p. m.	1,030.65	+11.22	+ 16.03	114.27	98.24	68.77	60.89	.8855
	10 p. m. to 1 a. m.	1,056.73	+26.08	+ 37.26	95.97	58.71	41.10	42.99	1.0490
	Total, 6 hours	....	+37.30	+ 53.29	210.24	156.95	109.87	103.88	.9455
	1 a. m. to 4 a. m.	1,058.65	+ 1.92	+ 2.74	55.20	52.46	36.72	32.51	.8853
	4 a. m. to 7 a. m.	1,056.10	− 2.55	− 3.64	61.20	64.84	45.39	37.08	.8169
	Total, 6 hours	....	− .63	− .90	116.40	117.30	82.11	69.59	.8474
	Total, 1 day	....	+70.69	+100.99	724.40	623.41	436.38	392.35	.8991

Table 114.—*Record of oxygen in ventilating air current and respiratory quotient, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Oxygen.					(*f*)	(*g*)	(*h*)
		(*a*) Total amount in chamber at end of period.	Gain (+) or loss (−) over preceding period. (*b*) Volume.	Gain (+) or loss (−) over preceding period. (*c*) Weight, *b*÷0.7.	(*d*) Amount admitted to chamber.	(*e*) Corrected amounts consumed by subject, *d*−*c*.	Volume of oxygen consumed, *e*×0.7.	Volume of carbon dioxid exhaled.	Respiratory quotient, *g*÷*f*.
	Experiment No. 60—Continued.								
1904.		*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Jan. 28-29..	7 a. m. to 10 a.m...	984.38	− 71.72	−102.46	11.33	113.79	79.66	63.59	0.7982
	10 a. m. to 1 p. m...	926.81	− 57.57	− 82.24	1.82	84.06	58.84	52.28	.8885
	Total, 6 hours	....	−129.29	−184.70	13.15	197.85	138.50	115.87	.8366
	1 p. m. to 4 p. m...	903.37	− 23.44	− 33.49	57.00	90.49	63.34	55.26	.8725
	4 p. m. to 7 p. m...	901.27	− 2.10	− 3.00	77.03	80.03	56.02	50.65	.9041
	Total, 6 hours	....	− 25.54	− 36.49	134.03	170.52	119.36	105.91	.8873
	7 p. m. to 10 p. m...	886.40	− 14.87	− 21.24	78.08	99.32	69.52	64.59	.9290
	10 p. m. to 1 a. m...	881.74	− 4.66	− 6.66	45.45	52.11	36.48	36.10	.9895
	Total, 6 hours	....	− 19.53	− 27.90	123.53	151.43	106.00	100.69	.9500
	1 a. m. to 4 a. m....	865.88	− 15.86	− 22.66	30.36	53.02	37.11	32.66	.8801
	4 a. m. to 7 a. m....	845.10	− 20.78	− 29.69	24.76	54.45	38.12	32.46	.8516
	Total, 6 hours	....	− 36.64	− 52.35	55.12	107.47	75.23	65.12	.8656
	Total, 1 day..	....	−211.00	−301.44	325.83	627.27	439.09	387.59	.8827
Jan. 29-30..	7 a. m. to 10 a. m...	892.13	+ 47.03	+ 67.19	164.77	97.58	68.31	60.33	.8822
	10 a. m. to 1 p. m...	932.79	+ 40.66	+ 58.09	149.23	91.14	63.80	59.18	.9282
	Total, 6 hours	....	+ 87.69	+125.28	314.00	188.72	132.11	119.51	.9046
	1 p. m. to 4 p. m...	905.50	− 27.29	− 38.99	51.71	90.70	63.49	57.88	.9117
	4 p. m. to 7 p. m...	919.83	+ 14.33	+ 20.47	110.44	89.97	62.97	62.88	.9985
	Total, 6 hours.	....	− 12.96	− 18.52	162.15	180.67	126.46	120.76	.9549
	7 p. m. to 10 p. m...	891.93	− 27.90	− 39.86	53.58	93.44	65.41	60.48	.9246
	10 p. m. to 1 a. m...	916.75	+ 24.82	+ 35.46	91.08	55.62	38.93	42.04	1.0800
	Total, 6 hours	....	− 3.08	− 4.40	144.66	149.06	104.34	102.52	.9824
	1 a. m. to 4 a. m....	924.42	+ 7.67	+ 10.96	68.30	57.34	40.14	33.04	.8232
	4 a. m. to 7 a. m....	930.29	+ 5.87	+ 8.39	68.32	59.93	41.95	35.40	.8439
	Total, 6 hours	....	+ 13.54	+ 19.35	136.62	117.27	82.09	68.44	.8337
	Total, 1 day..	....	+ 85.19	+121.71	757.43	635.72	445.00	411.23	.9243
	Total, 3 days.	....	− 55.12	− 78.74	1,807.66	1,886.40	1,320.47	1,191.17	.9021
	Experiment No. 61.								
Jan. 30-31..	7 a. m. to 10 a. m...	835.31	− 94.98	−135.69	130.73	266.42	186.49	185.18	.9930
	10 a. m. to 1 p. m...	840.35	+ 5.04	+ 7.20	340.97	333.77	233.64	201.85	.8638
	Total, 6 hours	....	− 89.94	−128.49	471.70	600.19	420.13	387.03	.9212
	1 p. m. to 4 p. m...	851.23	+ 10.88	+ 15.54	235.58	220.04	154.03	136.13	.8838
	4 p. m. to 7 p. m...	874.98	+ 23.75	+ 33.93	206.79	172.85	120.99	107.49	.8901
	Total, 6 hours	....	+ 34.63	+ 49.47	442.36	392.89	275.02	243.62	.8858
	7 p. m. to 10 p. m...	886.95	+ 11.97	+ 17.10	124.13	107.03	74.92	60.06	.8017
	10 p. m. to 1 a. m...	883.57	− 3.38	− 4.83	69.51	74.34	52.04	45.68	.8778
	Total, 6 hours	....	+ 8.59	+ 12.27	193.64	181.37	126.96	105.74	.8328
	1 a. m. to 4 a. m....	889.54	+ 5.97	+ 8.53	80.74	72.21	50.54	42.02	.8314
	4 a. m. to 7 a. m....	891.29	+ 1.75	+ 2.50	64.93	62.43	43.70	35.95	.8227
	Total, 6 hours	....	+ 7.72	+ 11.03	145.67	134.64	94.24	77.97	.8273
	Total, 1 day..	....	− 39.00	− 55.72	1,253.37	1,309.09	916.35	814.36	.8887

Table 114.—*Record of oxygen in ventilating air current and respiratory quotient, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Oxygen. (a) Total amount in chamber at end of period.	Oxygen. Gain (+) or loss (−) over preceding period. (b) Volume.	Oxygen. Gain (+) or loss (−) over preceding period. (c) Weight, b÷0.7.	Oxygen. (d) Amount admitted to chamber.	Oxygen. (e) Corrected amounts consumed by subject, d − c.	(f) Volume of oxygen consumed, e×0.7.	(g) Volume of carbon dioxid exhaled.	(h) Respiratory quotient, g÷f.
	Experiment No. 62.								
1904.		*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Apr. 16	7 a. m	846.76	....	....	....	....	....	....	....
Apr. 16–17.	7 a. m. to 10 a. m	769.73	−77.03	−110.04	157.12	267.16	187.01	171.83	0.9189
	10 a. m. to 1 p. m	821.97	+52.24	+ 74.63	329.18	254.55	178.19	158.67	.8905
	Total, 6 hours	....	−24.79	− 35.41	486.30	521.71	365.20	330.50	.9050
	1 p. m. to 4 p. m	801.19	−20.78	− 29.69	230.80	260.49	182.34	162.71	.8923
	4 p. m. to 7 p. m	835.93	+34.74	+ 49.63	307.44	257.81	180.47	164.82	.9133
	Total, 6 hours	....	+13.96	+ 19.94	538.24	518.30	362.81	327.53	.9028
	7 p. m. to 10 p. m	868.13	+32.20	+ 46.00	147.87	101.87	71.31	58.00	.8133
	10 p. m. to 1 a. m	859.56	− 8.57	− 12.24	80.67	92.91	65.04	58.28	.8961
	Total, 6 hours	....	+23.63	+ 33.76	228.54	194.78	136.35	116.28	.8528
	1 a. m. to 4 a. m	874.34	+14.78	+ 21.11	89.11	68.00	47.60	48.05	1.0095
	4 a. m. to 7 a. m	876.75	+ 2.41	+ 3.44	72.32	68.88	48.22	41.04	.8511
	Total, 6 hours	....	+17.19	+ 24.55	161.43	136.88	95.82	89.09	.9298
	Total, 1 day	....	+29.99	+ 42.84	1,414.51	1,371.67	960.18	863.40	.8992
Apr. 17–18	7 a. m. to 10 a. m	785.48	−91.27	−130.39	154.19	284.58	199.21	174.26	.8747
	10 a. m. to 1 p. m	813.42	+27.94	+ 39.91	292.99	253.08	177.16	169.48	.9566
	Total, 6 hours	....	−63.33	− 90.48	447.18	537.66	376.37	343.74	.9133
	1 p. m. to 4 p. m	775.65	−37.77	− 53.96	202.55	256.51	179.56	164.08	.9138
	4 p. m. to 7 p. m	794.25	+18.60	+ 26.57	279.23	252.66	176.86	160.23	.9060
	Total, 6 hours	....	−19.17	− 27.39	481.78	509.17	356.42	324.31	.9099
	7 p. m. to 10 p. m	814.38	+20.13	+ 28.76	141.54	112.78	78.95	70.72	.8958
	10 p. m. to 1 a. m	806.98	− 7.40	− 10.57	74.49	85.06	59.54	54.88	.9217
	Total, 6 hours	....	+12.73	+ 18.19	216.03	197.84	138.49	125.60	.9069
	1 a. m. to 4 a. m	806.46	− .52	− .74	71.45	72.19	50.53	41.66	.8245
	4 a. m. to 7 a. m	805.10	− 1.36	− 1.94	68.87	70.81	49.57	42.58	.8590
	Total, 6 hours	....	− 1.88	− 2.68	140.32	143.00	100.10	84.24	.8416
	Total, 1 day	....	−71.65	−102.36	1,285.31	1,387.67	971.38	877.89	.9038
Apr. 18–19	7 a. m. to 10 a. m	745.10	−60.00	− 85.71	188.27	273.98	191.79	168.42	.8781
	10 a. m. to 1 p. m	755.46	+10.36	+ 14.80	275.21	260.41	182.29	166.38	.9127
	Total, 6 hours	....	−49.64	− 70.91	463.48	534.39	374.08	334.80	.8950
	1 p. m. to 4 p. m	751.01	− 4.45	− 6.36	270.48	276.84	193.79	171.00	.8824
	4 p. m. to 7 p. m	769.94	+18.93	+ 27.04	267.28	240.24	168.17	148.83	.8850
	Total, 6 hours	....	+14.48	+ 20.68	538.76	517.08	361.96	319.83	.8836
	7 p. m. to 10 p. m	782.14	+12.20	+ 17.43	137.79	120.36	84.25	76.76	.9111
	10 p. m. to 1 a. m	793.01	+10.87	+ 15.53	90.53	75.00	52.50	47.35	.9019
	Total, 6 hours	....	+23.07	+ 32.96	228.32	195.36	136.75	124.11	.9076
	1 a. m. to 4 a. m	777.36	−15.65	− 22.36	54.01	76.37	53.46	43.70	.8174
	4 a. m. to 7 a. m	776.52	− .84	− 1.20	74.86	76.06	53.24	44.06	.8276
	Total, 6 hours	....	−16.49	− 23.56	128.87	152.43	106.70	87.76	.8225
	Total, 1 day	....	−28.58	− 40.83	1,358.43	1,399.26	979.49	866.50	.8845
	Total, 3 days	....	−70.24	−100.35	4,058.25	4,158.60	2,911.05	2,607.79	.8959

Table 114.—*Record of oxygen in ventilating air current and respiratory quotient, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Oxygen. (a) Total amount in chamber at end of period.	Oxygen. Gain (+) or loss (−) over preceding period. (b) Volume.	Oxygen. Gain (+) or loss (−) over preceding period. (c) Weight, $b \div 0.7$.	Oxygen. (d) Amount admitted to chamber.	Oxygen. (e) Corrected amounts consumed by subject, $d-c$.	(f) Volume of oxygen consumed, $e \times 0.7$.	(g) Volume of carbon dioxid exhaled.	(h) Respiratory quotient, $g \div f$.
	Experiment No. 63.	*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
1904. Apr. 18–19..	7 a. m.	776.52	....	....	....	....	....	....	....
Apr. 19–20..	7 a. m. to 10 a. m.	718.03	− 58.49	− 83.56	202.86	286.42	200.49	167.64	0.8362
	10 a. m. to 1 p. m.	754.86	+ 36.83	+ 52.61	304.45	251.84	176.29	153.37	.8691
	Total, 6 hours	....	− 21.66	− 30.95	507.31	538.26	376.78	321.01	.8520
	1 p. m. to 4 p. m.	723.12	− 31.74	− 45.34	239.08	284.42	199.09	163.99	.8237
	4 p. m. to 7 p. m.	766.12	+ 43.00	+ 61.43	290.60	229.17	160.42	130.57	.8139
	Total, 6 hours	....	+ 11.26	+ 16.09	529.68	513.59	359.51	294.56	.8194
	7 p. m. to 10 p. m.	778.35	+ 12.23	+ 17.47	134.41	116.94	81.86	62.21	.7600
	10 p. m. to 1 a. m.	771.98	− 6.37	− 9.10	75.77	84.87	59.41	52.95	.8913
	Total, 6 hours	....	+ 5.86	+ 8.37	210.18	201.81	141.27	115.16	.8152
	1 a. m. to 4 a. m.	767.49	− 4.49	− 6.41	73.65	80.06	56.04	42.62	.7605
	4 a. m. to 7 a. m.	754.62	− 12.87	− 18.39	56.78	75.17	52.62	42.07	.7995
	Total, 6 hours	....	− 17.36	− 24.80	130.43	155.23	108.66	84.69	.7796
	Total, 1 day	....	− 21.90	− 31.29	1,377.60	1,408.89	986.22	815.42	.8268
Apr. 20–21.	7 a. m. to 10 a. m.	702.81	− 51.81	− 74.01	217.51	291.52	204.06	163.65	.8020
	10 a. m. to 1 p. m.	732.64	+ 29.83	+ 42.61	302.86	260.25	182.18	154.36	.8473
	Total, 6 hours	....	− 21.98	− 31.41	520.37	551.77	386.24	318.01	.8234
	1 p. m. to 4 p. m.	758.95	+ 26.31	+ 37.59	316.19	278.60	195.02	153.34	.7863
	4 p. m. to 7 p. m.	777.28	+ 18.33	+ 26.19	269.24	243.05	170.14	134.04	.7878
	Total, 6 hours	....	+ 44.64	+ 63.78	585.43	521.65	365.16	287.38	.7870
	7 p. m. to 10 p. m.	851.78	+ 74.50	+106.43	225.18	118.75	83.13	63.01	.7580
	10 p. m. to 1 a. m.	856.90	+ 5.12	+ 7.31	107.67	100.36	70.25	55.89	.7956
	Total, 6 hours.	....	+ 79.62	+113.74	332.85	219.11	153.38	118.90	.7752
	1 a. m. to 4 a. m.	874.77	+ 17.87	+ 25.53	100.85	75.32	52.72	35.72	.6775
	4 a. m. to 7 a. m.	865.16	− 9.61	− 13.73	72.42	86.15	60.31	44.81	.7430
	Total, 6 hours	....	+ 8.26	+ 11.80	173.27	161.47	113.03	80.53	.7125
	Total, 1 day	....	+110.54	+157.92	1,611.92	1,454.00	1,017.81	804.82	.7907
Apr. 21–22.	7 a. m. to 10 a. m.	855.85	− 9.31	− 13.30	264.76	278.06	194.64	156.45	.8038
	10 a. m. to 1 p. m.	881.71	+ 25.86	+ 36.94	302.20	265.26	185.68	146.28	.7878
	Total, 6 hours	....	+ 16.55	+ 23.64	566.96	543.32	380.32	302.73	.7960
	1 p. m. to 4 p. m.	905.07	+ 23.36	+ 33.37	329.71	296.34	207.44	163.59	.7886
	4 p. m. to 7 p. m.	940.42	+ 35.35	+ 50.50	283.45	232.95	163.07	133.80	.8205
	Total, 6 hours	....	+ 58.71	+ 83.87	613.16	529.29	370.51	297.39	.8227
	7 p. m. to 10 p. m.	1,012.66	+ 72.24	+103.20	229.55	126.35	88.45	63.52	.7181
	10 p. m. to 1 a. m.	1,019.65	+ 6.99	+ 9.99	104.10	94.11	65.88	54.56	.8282
	Total, 6 hours	....	+ 79.23	+113.19	333.65	220.46	154.33	118.08	.7651
	1 a. m. to 4 a. m.	1,021.37	+ 1.72	+ 2.46	87.58	85.12	59.58	44.04	.7392
	4 a. m. to 7 a. m.	1,033.12	+ 11.75	+ 16.79	92.94	76.15	53.31	41.34	.7755
	Total, 6 hours	....	+ 13.47	+ 19.25	180.52	151.27	112.89	85.38	.7562
	Total, 1 day	....	+167.96	+239.95	1,694.29	1,454.34	1,018.05	803.58	.7893
	Total, 3 days.	....	+256.60	+366.58	4,683.81	4,317.23	3,022.08	2,423.82	.8020

TABLE 114.—*Record of oxygen in ventilating air current and respiratory quotient, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Oxygen.					(*f*)	(*g*)	(*h*)
		(*a*)	Gain (+) or loss (−) over preceding period.		(*d*)	(*e*)			
		Total amount in chamber at end of period.	(*b*) Volume.	(*c*) Weight, *b*÷0.7.	Amount admitted to chamber.	Corrected amounts consumed by subject, *d* − *c*.	Volume of oxygen consumed, *e*×0.7.	Volume of carbon dioxid exhaled.	Respiratory quotient, *g*÷*f*.
	Experiment No. 64.								
1904.		*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Apr. 21–22	7 a. m.	1,033.12	....	....	....	....	....	....	....
Apr. 22–23.	7 a. m. to 10 a. m.	990.47	− 42.65	− 60.93	277.38	338.31	236.82	187.60	0.7922
	10 a. m. to 1 p. m.	1,017.10	+ 26.63	+ 38.04	308.70	270.66	189.46	155.10	.8186
	Total, 6 hours	....	− 15.02	− 22.89	586.08	608.97	426.28	342.70	.8039
	1 p. m. to 4 p. m.	976.15	− 40.95	− 58.50	284.17	342.67	239.87	199.60	.8321
	4 p. m. to 7 p. m.	1,007.64	+ 31.49	+ 44.99	331.36	286.37	200.46	171.27	.8544
	Total, 6 hours	....	− 8.46	− 13.51	615.53	629.04	440.33	370.87	.8424
	7 p. m. to 10 p. m.	970.01	− 37.63	− 53.76	285.27	339.03	237.32	195.53	.8239
	10 p. m. to 1 a. m.	1,007.14	+ 37.13	+ 53.04	290.30	237.26	166.08	127.11	.7654
	Total, 6 hours	....	− .50	− .72	575.57	576.29	403.40	322.64	.7998
	1 a. m. to 4 a. m.	1,012.89	+ 5.75	+ 8.21	217.56	209.35	146.55	113.75	.7762
	4 a. m. to 7 a. m.	1,028.45	+ 15.56	+ 22.23	104.23	82.00	57.40	43.37	.7556
	Total, 6 hours	....	+ 21.31	+ 30.44	321.79	291.35	203.95	157.12	.7704
	Total, 1 day.	....	− 4.67	− 6.68	2,098.97	2,105.65	1,473.96	1,193.33	.8096
	Experiment No. 65.								
Apr. 23–24.	7 a. m. to 10 a. m.	1,015.95	− 12.50	− 17.86	89.63	107.49	75.24	57.57	.7652
	10 a. m. to 1 p. m.	1,015.76	− .19	− .27	75.85	76.12	53.28	43.79	.8219
	Total, 6 hours	....	− 12.69	− 18.13	165.48	183.61	128.52	101.36	.7887
	1 p. m. to 4 p. m.	1,001.78	− 13.98	− 19.97	80.65	100.62	70.43	56.25	.7987
	4 p. m. to 7 p. m.	1,003.80	+ 2.02	+ 2.89	87.39	84.50	59.15	49.13	.8306
	Total, 6 hours	....	− 11.96	− 17.08	168.04	185.12	129.58	105.38	.8132
	7 p. m. to 10 p. m.	991.71	− 12.09	− 17.27	96.03	113.30	79.31	61.03	.7695
	10 p. m. to 1 a. m.	979.64	− 12.07	− 17.24	87.45	104.69	73.28	64.55	.8809
	Total, 6 hours	....	− 24.16	− 34.51	183.48	217.99	152.59	125.58	.8230
	1 a. m. to 4 a. m.	975.50	− 4.14	− 5.91	68.31	74.22	51.95	43.23	.8321
	4 a. m. to 7 a. m.	979.78	+ 4.28	+ 6.11	74.33	68.22	47.75	39.39	.8249
	Total, 6 hours	....	+ .14	+ .20	142.64	142.44	99.70	82.62	.8287
	Total, 1 day.	....	− 48.67	− 69.52	659.64	729.16	510.39	414.94	.8130
	Experiment No. 66.								
Apr. 24–25	7 a. m. to 10 a. m.	961.85	− 17.93	− 25.61	89.58	115.19	80.63	66.34	.8228
	10 a. m. to 1 p. m.	946.90	− 14.95	− 21.36	81.01	102.37	71.66	60.61	.8458
	Total, 6 hours	....	− 32.88	− 46.97	170.59	207.56	152.29	126.95	.8336
	1 p. m. to 4 p. m.	939.72	− 7.18	− 10.26	84.88	95.14	66.60	57.87	.8689
	4 p. m. to 7 p. m.	928.05	− 11.67	− 16.67	77.11	93.78	65.65	60.39	.9199
	Total, 6 hours	....	− 18.85	− 26.93	161.99	188.92	132.25	118.26	.8942
	7 p. m. to 10 p. m.	918.76	− 9.29	− 13.27	74.12	87.39	61.17	54.57	.8921
	10 p. m. to 1 a. m.	915.77	− 2.99	− 4.27	61.31	65.58	45.91	49.44	1.0769
	Total, 6 hours	....	− 12.28	− 17.54	135.43	152.97	107.08	104.01	.9713

TABLE 114.—*Record of oxygen in ventilating air current and respiratory quotient, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Date.	Period.	Oxygen.					(*f*)	(*g*)	(*h*)
		(*a*) Total amount in chamber at end of period.	Gain (+) or loss (−) over preceding period.		(*d*) Amount admitted to chamber.	(*e*) Corrected amounts consumed by subject, *d*−*c*.	Volume of oxygen consumed, *e*×0.7.	Volume of carbon dioxid exhaled.	Respiratory quotient, *g*÷*f*.
			(*b*) Volume.	(*c*) Weight, *b*÷0.7.					
	Experiment No. 66—Continued.								
1904.		*Liters.*	*Liters.*	*Grams.*	*Grams.*	*Grams.*	*Liters.*	*Liters.*	
Apr. 24-25 .	1 a. m. to 4 a. m.....	891.86	− 23.91	− 34.16	45.95	80.11	56.08	37.98	0.6772
	4 a. m. to 7 a. m.....	882.50	− 9.36	− 13.37	54.07	67.44	47.21	40.32	.8541
	Total, 6 hours	....	− 33.27	− 47.53	100.02	147.55	103.29	78.30	.7581
	Total, 1 day..	....	− 97.28	−138.97	568.03	707.00	494.91	427.52	.8639
	Experiment No. 67.								
Apr. 25-26 .	7 a. m. to 10 a. m....	852.73	− 29.77	− 42.53	88.12	130.65	91.46	76.42	.8356
	10 a. m. to 1 p. m....	840.36	− 12.37	− 17.67	100.64	118.31	82.82	70.43	.8504
	Total, 6 hours	....	− 42.14	− 60.20	188.76	248.96	174.28	146.85	.8426
	1 p. m. to 4 p. m	832.38	− 7.98	− 11.40	98.22	109.62	76.73	69.96	.9118
	4 p. m. to 7 p. m....	839.10	+ 6.92	+ 9.60	127.80	118.20	82.74	70.60	.8533
	Total, 6 hours	....	− 1.06	− 1.80	226.02	227.82	159.47	140.56	.8814
	7 p. m. to 10 p. m...	854.18	+ 15.08	+ 21.54	115.06	93.52	65.46	60.02	.9169
	10 p. m. to 1 a. m....	846.51	− 7.67	− 10.96	79.20	90.16	63.11	58.61	.9287
	Total, 6 hours	....	+ 7.41	+ 10.58	194.26	183.68	128.57	118.63	.9227
	1 a. m. to 4 a. m.....	854.05	+ 7.54	+ 10.77	79.44	68.67	48.07	39.84	.8288
	4 a. m. to 7 a. m.....	865.82	+ 11.77	+ 16.81	78.71	61.90	43.33	38.56	.8899
	Total, 6 hours	....	+ 19.31	+ 27.58	158.15	130.57	91.40	78.40	.8578
	Total, 1 day..	....	− 16.68	− 23.84	767.19	791.03	553.72	484.44	.8750
Apr. 26-27 .	7 a. m. to 10 a. m....	887.19	+ 21.37	+ 30.53	168.06	137.53	96.27	79.31	.8238
	10 a. m. to 1 p. m....	887.10	− .09	− .13	117.35	117.48	82.24	69.70	.8475
	Total, 6 hours	....	+ 21.28	+ 30.40	185.41	255.01	178.51	149.01	.8347
	1 p. m. to 4 p. m....	868.18	− 18.92	− 27.03	112.70	139.73	97.81	84.20	.8609
	4 p. m. to 7 p. m....	895.74	+ 27.56	+ 39.37	142.45	103.08	72.16	67.47	.9350
	Total, 6 hours	....	+ 8.64	+ 12.34	255.15	142.81	169.97	151.67	.8923
	7 p. m. to 10 p. m...	904.51	+ 8.77	+ 12.53	101.50	88.97	62.28	57.07	.9163
	10 p. m. to 1 a. m....	902.78	− 1.73	− 2.47	76.59	79.06	55.34	51.81	.9362
	Total, 6 hours	....	+ 7.04	+ 10.06	178.09	168.03	117.62	108.88	.9257
	1 a. m. to 4 a. m.....	905.94	+ 3.16	+ 4.51	74.68	70.17	49.12	37.82	.7598
	4 a. m. to 7 a. m.....	913.56	+ 7.62	+ 10.89	72.74	61.85	43.30	37.83	.8737
	Total, 6 hours	....	+ 10.78	+ 15.40	147.42	132.02	92.42	75.65	.8185
	Total, 1 day..	....	+ 47.74	+ 68.20	866.07	797.87	558.52	484.71	.8679
	Total, 2 days.	....	+ 31.06	+ 44.36	1,633.26	1,588.90	1,112.24	969.15	.8713

TABLE 115.—*Oxygen consumed by subjects in 3-hour periods, metabolism experiments Nos. 56–58 and 60–67.*

Kind and number of experiments.	Day.	7 a. m. to 10 a. m.	10 a. m. to 1 p. m.	Total, 6 hours.	1 p. m. to 4 p. m.	4 p. m. to 7 p. m.	Total, 6 hours.	7 p. m. to 10 p. m.	10 p. m. to 1 a. m.	Total, 6 hours.	1 a. m. to 4 a. m.	4 a. m. to 7 a. m.	Total, 6 hours.	Total, 1 day.
Rest experiments, carbohydrate diet.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 58[a]	1	....	....	121.70	....	....	150.43	....	....	138.25	....	....	118.12	528.50
No. 58	2	....	....	155.57	....	....	135.42	....	....	138.41	....	....	119.58	548.98
No. 58	3	....	....	157.23	....	....	156.59	....	....	146.71	....	....	128.60	589.13
Average per day				144.83	....	....	147.48	....	....	141.12	....	....	122.10	555.54
No. 60	1	110.42	73.62	184.04	88.33	76.79	165.12	98.24	58.71	156.95	52.46	64.84	117.30	623.41
No. 60	2	113.79	84.06	197.85	90.49	80.03	170.52	99.32	52.11	151.43	53.02	54.45	107.47	627.27
No. 60	3	97.58	91.14	188.72	90.70	89.97	180.67	93.44	55.62	149.06	57.34	59.93	117.27	635.72
Average per day	......	107.26	82.94	190.20	89.84	82.26	172.10	97.00	55.48	152.48	54.27	59.74	114.01	628.80
No. 65	1	107.49	76.12	183.61	100.62	84.50	185.12	113.30	104.69	217.99	74.22	68.22	142.44	729.16
No. 66	1	115.19	102.37	217.56	95.14	93.78	188.92	87.39	65.58	152.97	80.11	67.44	147.55	707.00
No. 67	1	130.65	118.31	248.96	109.62	118.20	227.82	93.52	90.16	183.68	68.67	61.90	130.57	791.03
No. 67	2	137.53	117.48	255.01	139.73	103.08	242.81	88.97	79.06	168.03	70.17	61.85	132.02	797.87
Average per day	......	134.09	117.90	251.99	124.68	110.64	235.32	91.25	84.61	175.86	69.42	61.88	131.30	794.45
Average Nos. 65, 66, and 67	......	122.72	103.57	226.29	111.28	99.89	211.17	95.80	84.87	180.67	73.29	64.85	138.14	756.27
Average, Nos. 58, 60, 65, 66, and 67	......	116.09	94.73	210.82	102.09	92.33	194.42	96.31	72.28	168.59	65.14	62.66	127.80	701.64
Work experiments, carbohydrate diet.														
No. 57	1	290.65	355.86	646.51	286.16	322.19	608.35	113.88	88.72	202.60	89.20	62.10	151.30	1,608.76
No. 57	2	241.51	291.86	533.37	252.83	335.63	588.46	123.32	87.83	211.15	160.58	69.27	229.85	1,562.83
No. 57	3	300.82	410.63	711.45	355.94	160.18	516.12	106.90	85.73	192.63	66.48	70.11	136.59	1,556.79
Average per day	......	277.66	352.78	630.44	298.31	272.66	570.98	114.70	87.42	202.13	105.42	67.16	172.58	1,576.13
No. 61	1	266.42	333.77	600.19	220.04	172.85	392.89	107.03	74.34	181.37	72.21	62.43	134.64	1,309.09

[a] During the first day of No. 56, records were made only by 6-hour periods.

TABLE 115.—*Oxygen consumed by subjects in 3-hour periods, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Kind and number of experiments.	Day.	7 a. m. to 10 a. m.	10 a. m. to 1 p. m.	Total 6 hours.	1 p. m. to 4 p. m.	4 p. m. to 7 p. m.	Total 6 hours.	7 p. m. to 10 p. m.	10 p. m. to 1 a. m.	Total 6 hours.	1 a. m. to 4 a. m.	4 a. m. to 7 a. m.	Total 6 hours.	Total 1 day.
Work experiments, carbohydrate diet—Continued.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No. 62	1	267.16	254.55	521.71	260.49	257.81	518.30	101.87	92.91	194.78	68.00	68.88	136.88	1,371.67
No. 62	2	284.58	253.08	537.66	256.51	252.66	509.17	112.78	85.06	197.84	72.19	70.81	143.00	1,387.67
No. 62	3	273.98	260.41	534.39	276.84	240.24	517.08	120.36	75.00	195.36	76.37	76.06	152.43	1,399.26
Average per day	......	275.24	256.01	531.25	264.61	250.24	514.85	111.67	84.32	195.99	72.19	71.92	144.10	1,386.20
Average, Nos. 57, 61, and 62	......	275.02	308.59	583.61	272.69	248.79	521.48	112.31	84.23	196.53	86.43	68.52	154.96	1,456.58
Work experiments, fat diet.														
No. 56[a]	1	......	......	584.39	......	......	602.60	......	......	204.54	......	......	153.71	1,545.24
No. 56	2	342.13	360.15	702.28	332.64	251.87	584.51	122.22	91.93	214.15	80.89	70.73	151.62	1,652.56
No. 56	3	301.51	250.88	552.39	313.78	288.99	602.77	110.12	106.08	216.20	81.63	64.81	146.44	1,517.80
Average per day	......	321.82	305.52	613.02	323.21	270.43	596.63	116.17	99.01	211.63	81.26	67.77	150.59	1,571.87
No. 63	1	286.42	251.84	538.26	284.42	229.17	513.59	116.94	84.87	201.81	80.06	75.17	155.23	1,408.89
No. 63	2	291.52	260.25	551.77	278.60	243.05	521.65	118.75	100.36	219.11	75.32	86.15	161.47	1,454.00
No. 63	3	278.06	265.26	543.32	296.34	232.95	529.29	126.35	94.11	220.46	85.12	76.15	161.27	1,454.34
Average per day	......	285.33	259.12	544.45	286.45	235.06	521.51	120.68	93.11	213.79	80.17	79.16	159.32	1,439.08
Average, Nos. 56 and 63	......	299.93	277.68	578.74	301.16	249.21	559.07	118.88	95.47	212.71	80.60	74.60	154.96	1,505.47
Average, Nos. 56, 57, 61, 62, and 63	......	285.40	295.71	581.36	284.55	248.97	538.83	115.04	88.91	204.00	84.00	71.06	154.96	1,479.15
Severe work, fat diet.														
No. 64	1	338.31	270.66	608.97	342.67	286.37	629.04	339.03	237.26	576.29	209.35	82.00	291.36	2,105.65
Average, Nos. 56, 57, 61, 62, 63, and 64	......	289.47	293.78	583.33	289.02	251.84	545.27	132.27	100.32	230.59	93.65	71.90	164.70	1,523.90

[a] During No. 58, records were made only by 6-hour periods.

TABLE 116.—*Summary of calorimetric measurements, metabolism experiments Nos. 56–58 and 60–67, inclusive.*

Date.	Period.	(*a*) Heat measured in terms of C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b* × 60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total excess in outgoing air plus excess residual vapor.	(*f*) Heat rendered latent in vaporization of water, *e* × 0.592.	(*g*) Total heat determined, *a* + *c* + *d* + *f*.
	Experiment No. 56.							
1903.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 27–28	7 a. m. to 1 p. m	1,851.6	−0.05	− 3.0	− 12.7	283.4	167.8	2,003.7
	1 p. m. to 7 p. m	1,830.5	+ .04	+ 2.4	− 29.8	308.5	182.6	1,985.7
	7 p. m. to 1 a. m	570.4	....	....	+ 4.6	342.7	202.9	777.9
	1 a. m. to 7 a. m	342.0	....	....	....	314.0	185.9	527.9
	Total, 1 day	4,594.5	− .01	− .6	− 37.9	1,248.6	739.2	5,295.2
Apr. 28–29	7 a. m. to 1 p. m	2,002.9	+ .22	+13.2	− 10.3	333.1	197.2	2,203.0
	1 p. m. to 7 p. m	1,802.6	− .08	− 4.8	− 34.0	341.8	202.3	1,966.1
	7 p. m. to 1 a. m	518.1	+ .22	+13.2	+ 2.0	344.5	203.9	737.2
	1 a. m. to 7 a. m	334.0	− .08	− 4.8	....	334.3	197.9	527.1
	Total, 1 day	4,657.6	+ .28	+16.8	− 42.3	1,353.7	801.3	5,433.4
Apr. 29–30	7 a. m. to 1 p. m	1,679.9	− .10	− 6.0	− 8.9	316.8	187.5	1,852.5
	1 p. m. to 7 p. m	1,862.5	− .06	− 3.6	− 37.5	321.2	190.1	2,011.5
	7 p. m. to 1 a. m	534.7	+ .08	+ 4.8	+ 2.1	311.9	184.7	726.3
	1 a. m. to 7 a. m	366.1	− .12	− 7.2	....	295.1	174.7	533.6
	Total, 1 day	4,443.2	− .20	−12.0	− 44.3	1,245.0	737.0	5,123.9
	Total, 3 days	13,695.3	− .07	+ 4.2	−124.5	3,847.3	2,277.5	15,852.5
	Experiment No. 57.							
May 7–8	7 a. m. to 1 p. m	2,009.3	− .02	− 1.2	− 17.1	395.9	234.4	2,225.4
	1 p. m. to 7 p. m	1,904.4	+ .08	+ 4.8	− 39.0	422.2	249.9	2,120.1
	7 p. m. to 1 a. m	597.0	+ .32	+19.2	+ 5.4	237.5	140.6	762.2
	1 a. m. to 7 a. m	385.8	− .64	−38.4	....	215.0	127.3	474.7
	Total, 1 day	4,896.5	− .26	−15.6	− 50.7	1,270.6	752.2	5,582.4
May 8–9	7 a. m. to 1 p. m	1,758.1	+ .42	+25.2	− 13.9	329.4	195.0	1,964.4
	1 p. m. to 7 p. m	1,875.4	− .02	− 1.2	− 32.4	418.9	248.0	2,089.8
	7 p. m. to 1 a. m	585.7	− .03	− 1.8	+ 4.2	393.2	232.8	820.9
	1 a. m. to 7 a. m	276.3	+ .03	+ 1.8	....	379.3	224.5	502.6
	Total, 1 day	4,495.5	+ .40	+24.0	− 42.1	1,520.8	900.3	5,377.7
May 9–10	7 a. m. to 1 p. m	2,240.8	− .03	− 1.8	− 8.5	433.1	256.4	2,486.9
	1 p. m. to 7 p. m	1,481.7	....	....	− 31.3	335.9	198.9	1,649.3
	7 p. m. to 1 a. m	498.6	....	....	+ 3.6	369.6	218.8	721.0
	1 a. m. to 7 a. m	281.3	....	....	....	347.2	205.5	486.8
	Total, 1 day	4,502.4	− .03	− 1.8	− 36.2	1,485.8	879.6	5,344.0
	Total, 3 days	13,894.4	+ .11	+ 6.6	−129.0	4,277.2	2,532.1	16,304.1
	Experiment No. 58.							
Nov. 10–11	7 a. m. to 1 p. m	321.5	− .03	− 1.8	....	122.6	72.6	392.3
	1 p. m. to 7 p. m	470.1	+ .04	+ 2.4	+ 5.6	111.0	65.7	543.8
	7 p. m. to 1 a. m	406.3	− .05	− 3.0	+ 2.1	129.7	76.8	482.2
	1 a. m. to 7 a. m	315.7	....	....	....	143.8	85.1	400.8
	Total, 1 day	1,513.6	− .04	− 2.4	+ 7.7	507.1	300.2	1,819.1
Nov. 11–12	7 a. m. to 1 p. m	461.6	− .07	− 4.2	....	179.6	106.3	563.7
	1 p. m. to 7 p. m	285.9	+ .08	+ 4.8	+ 6.9	213.4	126.3	423.9
	7 p. m. to 1 a. m	294.2	+ .05	+ 3.0	+ 3.1	226.7	134.2	434.5
	1 a. m. to 7 a. m	304.4	− .08	− 4.8	....	209.1	123.8	423.4
	Total, 1 day	1,346.1	− .02	− 1.2	+ 10.0	828.8	490.6	1,845.5

Table 116.—*Summary of calorimetric measurements, metabolism experiments Nos. 56–58 and 60–67, inclusive*—Continued.

Date.	Period.	(a) Heat measured in terms of C_{20}.	(b) Change of temperature of calorimeter.	(c) Capacity correction of calorimeter, b×60.	(d) Correction due to temperature of food and dishes.	(e) Water vaporized equals total excess in outgoing air plus excess residual vapor.	(f) Heat rendered latent in vaporization of water c×0.592.	(g) Total heat determined, a+c+d+f.
	Experiment No. 58—Continued.							
		Calories.	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
1903. Nov. 12–13.	7 a. m. to 1 p. m....	474.0	+0.08	+ 4.8	+ 5.3	214.5	127.0	611.1
	1 p. m. to 7 p. m....	411.8	− .03	− 1.8	+ 4.9	190.1	112.6	527.5
	7 p. m. to 1 a. m....	337.2	+ .03	+ 1.8	....	214.1	126.7	465.7
	1 a. m. to 7 a. m....	326.3	− .01	− .6	....	198.2	117.3	443.0
	Total, 1 day...	1,549.3	+ .07	+ 4.2	+ 10.2	816.9	483.6	2,047.3
	Total, 3 days.	4,409.0	+ .01	+ .6	+ 27.9	2,152.8	1,274.4	5,711.9
	Experiment No. 60.							
1904. Jan. 27–28..	7 a. m. to 10 a. m...	285.8	− .01	− .6	− 9.7	134.9	79.9	355.4
	10 a. m. to 1 p. m...	223.9	− .03	− 1.8	+ .9	117.6	69.6	292.6
	Total, 6 hours.	509.7	− .04	− 2.4	− 8.8	252.5	149.5	648.0
	1 p. m. to 4 p. m....	226.2	+ .02	+ 1.2	....	124.4	73.6	301.0
	4 p. m. to 7 p. m....	216.1	+ .02	+ 1.2	+ 4.2	120.8	71.5	293.0
	Total, 6 hours.	442.3	+ .04	+ 2.4	+ 4.2	245.2	145.1	594.0
	7 p.m. to 10 p. m...	242.9	+ .02	+ 1.2	+ 4.7	128.8	76.3	325.1
	10 p. m. to 1 a. m...	172.7	− .02	− 1.2	....	113.9	67.4	238.9
	Total, 6 hours.	415.6	....	....	+ 4.7	242.7	143.7	564.0
	1 a. m. to 4 a. m....	141.2	....	....	....	104.5	61.9	203.1
	4 a. m. to 7 a. m....	136.4	....	....	....	114.6	67.8	204.2
	Total, 6 hours.	277.6	....	....	....	219.1	129.7	407.3
	Total, 1 day...	1,645.2	....	....	+ .1	959.5	568.0	2,213.3
Jan. 28–29..	7 a. m. to 10 a. m....	343.2	+ .05	+ 3.0	− .7	37.5	22.2	367.7
	10 a. m. to 1 p. m...	292.1	− .03	− 1.8	+ 3.7	16.7	9.9	303.9
	Total, 6 hours.	635.3	+ .02	+ 1.2	+ 3.0	54.2	32.1	671.6
	1 p. m. to 4 p. m....	284.4	+ .01	+ .6	− 1.8	32.0	19.0	302.2
	4 p. m. to 7 p. m....	272.7	− .07	− 4.2	+ 2.7	45.6	27.0	298.2
	Total, 6 hours.	557.1	− .06	− 3.6	+ .9	77.6	46.0	600.4
	7 p.m. to 10 p. m...	319.6	− .04	− 2.4	+ 4.7	38.9	23.0	344.9
	10 p. m. to 1 a. m...	197.6	− .05	− 3.0	....	40.9	24.2	218.8
	Total, 6 hours.	517.2	− .09	− 5.4	+ 4.7	79.8	47.2	563.7
	1 a. m. to 4 a. m....	166.2	....	....	....	31.2	18.5	184.7
	4 a. m. to 7 a. m.....	161.4	+ .03	+ 1.8	....	29.3	17.3	180.5
	Total, 6 hours.	327.6	+ .03	+ 1.8	....	60.5	35.8	365.2
	Total, 1 day ..	2,037.2	− .10	− 6.0	+ 8.6	272.1	161.1	2,200.9
Jan. 29–30..	7 a. m. to 10 a. m...	286.5	+ .11	+ 6.6	− 3.1	146.3	86.6	376.6
	10 a. m. to 1 p. m...	232.2	+ .04	+ 2.4	+ .8	137.9	81.6	317.0
	Total, 6 hours..	518.7	+ .15	+ 9.0	− 2.3	284.2	168.2	693.6
	1 p. m. to 4 p. m....	225.1	− .02	− 1.2	+ .3	145.1	85.9	310.0
	4 p. m. to 7 p. m....	230.1	− .03	− 1.8	+ 3.5	144.5	85.5	317.3
	Total, 6 hours.	455.1	− .05	− 3.0	+ 3.8	289.6	171.4	627.8
	7 p. m. to 10 p. m...	245.6	....	....	+ 4.6	148.7	88.0	338.2
	10 p. m. to 1 a. m...	141.6	+ .07	+ 4.2	....	141.2	83.7	229.5
	Total, 6 hours.	387.2	+ .07	+ 4.2	+ 4.6	289.9	171.7	567.7

TABLE 116.—*Summary of calorimetric measurements, metabolism experiments Nos. 56–58 and 60–67, inclusive*—Continued.

Date.	Period.	(*a*) Heat measured in terms of C$_{20}$.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b* × 60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total excess in outgoing air plus excess residual vapor.	(*f*) Heat rendered latent in vaporization of water, *e* × 0.592.	(*g*) Total heat determined, *a* + *c* + *d* + *f*.
	Experiment No. 60—Continued.							
1904.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Jan. 9–30..	1 a. m. to 4 a. m....	125.8	−0.05	− 3.0	....	121.9	72.2	195.0
	4 a. m. to 7 a. m....	118.3	....	....	....	114.1	67.6	185.9
	Total, 6 hours.	244.1	− .05	− 3.0	....	236.0	139.8	380.9
	Total, 1 day..	1,605.1	+ .12	+ 7.2	+ 6.1	1,099.7	651.1	2,269.5
	Total, 3 days.	5,287.5	+ .02	+ 1.2	+ 14.8	2,331.3	1,380.2	6,683.7
	Experiment No. 61.							
Jan. 30–31..	7 a. m. to 10 a. m...	782.0	+ .28	+16.8	+ 3.3	169.6	100.4	902.5
	10 a. m. to 1 p. m...	981.6	− .20	−12.0	+ 6.7	182.7	108.2	1,084.5
	Total, 6 hours.	1,763.6	+ .08	+ 4.8	+ 10.0	352.3	208.6	1,987.0
	1 p. m. to 4 p. m....	682.2	− .35	−21.0	+ 16.2	191.0	113.0	790.4
	4 p. m. to 7 p. m....	535.1	+ .35	+21.0	+ 11.0	179.2	106.1	673.2
	Total, 6 hours.	1,217.3	....	....	+ 27.2	370.2	219.1	1,463.6
	7 p. m. to 10 p. m...	255.2	− .10	− 6.0	+ 6.5	177.8	105.3	361.0
	10 p. m. to 1 a. m...	151.4	+ .08	+ 4.8	....	164.6	97.4	253.6
	Total, 6 hours.	406.6	− .02	− 1.2	+ 6.5	342.4	202.7	614.6
	1 a. m. to 4 a. m....	181.0	− .23	−13.8	....	159.6	94.5	261.7
	4 a. m. to 7 a. m....	147.7	+ .05	+ 3.0	....	147.6	87.4	238.1
	Total, 6 hours.	328.7	− .18	−10.8	....	307.2	181.9	499.8
	Total, 1 day..	3,716.2	− .12	− 7.2	+ 43.7	1,372.1	812.3	4,565.0
	Experiment No. 62.							
Apr. 16–17..	7 a. m. to 10 a. m...	779.5	+ .09	+ 5.4	+ 10.1	161.3	95.5	890.5
	10 a. m. to 1 p. m...	846.2	− .27	−16.2	+ 5.5	164.0	97.1	932.6
	Total, 6 hours.	1,625.7	− .18	−10.8	+ 15.6	325.3	192.6	1,823.1
	1 p. m. to 4 p. m....	749.8	+ .25	+15.0	+ 15.3	164.9	97.6	877.7
	4 p. m. to 7 p. m....	818.2	− .16	− 9.6	+ 14.0	177.6	105.2	927.8
	Total, 6 hours.	1,568.0	+ .09	+ 5.4	+ 29.3	342.5	202.8	1,805.5
	7 p. m. to 10 p. m...	262.7	+ .09	+ 5.4	+ 5.1	140.5	83.1	356.3
	10 p. m. to 1 a. m...	219.8	+ .16	+ 9.6	....	171.8	101.7	331.1
	Total, 6 hours.	482.5	+ .25	+15.0	+ 5.1	312.3	184.8	687.4
	1 a. m. to 4 a. m....	172.3	− .13	− 7.8	....	157.2	93.0	257.5
	4 a. m. to 7 a. m....	139.0	− .05	− 3.0	....	156.7	92.8	228.8
	Total, 6 hours.	311.3	− .18	−10.8	....	313.9	185.8	486.3
	Total, 1 day..	3,987.5	− .02	− 1.2	+ 50.0	1,294.0	766.0	4,802.3
Apr. 17–18..	7 a. m. to 10 a. m...	816.5	+ .01	+ 0.6	+ 9.5	176.6	104.5	931.1
	10 a. m. to 1 p. m...	844.3	− .02	− 1.2	+ 5.3	180.5	106.8	955.2
	Total, 6 hours.	1,660.8	− .01	− 0.6	+ 14.8	357.1	211.3	1,886.3
	1 p. m. to 4 p. m....	741.2	+ .02	+ 1.2	+ 13.7	162.7	96.3	852.4
	4 p. m. to 7 p. m....	754.7	− .02	− 1.2	+ 11.7	175.5	103.9	869.1
	Total, 6 hours.	1,495.9	....	....	+ 25.4	338.2	200.2	1,721.5

Table 116—*Summary of calorimetric measurements, metabolism experiments Nos. 56–58 and 60–67, inclusive*—Continued.

Date.	Period.	(*a*) Heat measured in terms of C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b* × 60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total excess in outgoing air plus excess residual vapor.	(*f*) Heat rendered latent in vaporization of water, *e* × 0.592.	(*g*) Total heat determined, *a* + *c* + *d* + *f*.
	Experiment No. 62—Continued.							
1904.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 17–18..	7 p. m. to 10 p. m...	270.8	+0.03	+ 1.8	+ 4.9	152.6	90.4	367.9
	10 p. m. to 1 a. m...	219.9	+ .02	+ 1.2	....	162.4	96.2	317.3
	Total, 6 hours.	490.7	+ .05	+ 3.0	+ 4.9	315.0	186.6	685.2
	1 a. m. to 4 a. m....	182.2	− .02	− 1.2	....	144.0	85.3	266.3
	4 a. m. to 7 a. m....	170.8	− .01	− .6	....	135.7	80.3	250.5
	Total, 6 hours.	353.0	− .03	− 1.8	....	279.7	165.6	516.8
	Total, 1 day..	4,000.4	+ .01	+ .6	+ 45.1	1,290.0	763.7	4,809.8
Apr. 18–19..	7 a. m. to 10 a. m...	781.1	+ .02	+ 1.2	− 1.7	167.5	99.2	879.8
	10 a. m. to 1 p. m...	887.4	− .07	− 4.2	+ 5.4	154.3	91.3	979.9
	Total, 6 hours.	1,668.5	− .05	− 3.0	+ 3.7	321.8	190.5	1,859.7
	1 p. m. to 4 p. m....	840.5	− .04	− 2.4	+ 14.1	155.5	92.1	944.3
	4 p. m. to 7 p. m....	710.7	+ .10	+ 6.0	+ 13.6	158.6	93.9	824.2
	Total, 6 hours.	1,551.2	+ .06	+ 3.6	+ 27.7	314.1	186.0	1,768.5
	7 p. m. to 10 p. m...	299.8	+ .10	+ 6.0	+ 5.1	132.5	78.4	389.3
	10 p. m. to 1 a. m...	227.2	− .04	− 2.4	....	140.7	83.4	308.2
	Total, 6 hours.	527.0	+ 06	+ 3.6	+ 5.1	273.2	161.8	697.5
	1 a. m. to 4 a. m....	200.0	− .06	− 3.6	....	134.3	79.5	275.9
	4 a. m. to 7 a. m....	163.4	+ .06	+ 3.6	....	141.5	83.7	250.7
	Total, 6 hours.	363.4	....	....	....	275.8	163.2	526.6
	Total, 1 day..	4,110.2	+ .07	+ 4.2	+ 36.5	1,184.9	701.4	4,852.3
	Total, 3 days.	12,098.1	+ .06	+ 3.6	+131.6	3,768.9	2,231.1	14,464.4
	Experiment No. 63.							
Apr. 19–20..	7 a. m. to 10 a. m...	831.9	− .02	− 1.2	+ 9.1	169.4	100.3	940.1
	10 a. m. to 1 p. m...	840.9	− .05	− 3.0	+ 5.6	173.8	102.9	946.4
	Total, 6 hours.	1,672.8	− .07	− 4.2	+ 14.7	343.2	203.2	1,886.5
	1 p. m. to 4 p. m....	849.0	− .09	− 5.4	+ 15.8	170.7	101.0	960.4
	4 p. m. to 7 p. m....	723.4	+ .10	+ 6.0	+ 8.2	177.6	105.1	842.7
	Total, 6 hours.	1,572.4	+ .01	+ .6	+ 24.0	348.3	206.1	1,803.1
	7 p. m. to 10 p. m...	307.7	+ .05	+ 3.0	+ 4.7	155.2	91.9	407.3
	10 p m. to 1 a. m...	217.4	+ .01	+ .6	....	163.8	97.0	315.0
	Total, 6 hours.	525.1	+ .06	+ 3.6	+ 4.7	319.0	188.9	722.3
	1 a. m. to 4 a. m....	184.2	− .04	− 2.4	....	157.8	93.4	275.2
	4 a. m. to 7 a. m....	166.6	− .03	− 1.8	....	160.2	94.8	259.6
	Total, 6 hours.	350.8	− .07	− 4.2	....	318.0	188.2	534.8
	Total, 1 day..	4,121.1	− .07	− 4.2	+ 43.4	1,328.5	786.4	4,946.7
Apr. 20–21..	7 a. m. to 10 a. m...	851.1	+ .08	+ 4.8	+ 14.5	178.7	105.8	976.2
	10 a. m. to 1 p. m...	890.1	− .16	− 9.6	....	164.3	97.3	977.8
	Total, 6 hours.	1,741.2	− .08	− 4.8	+ 14.5	343.0	203.1	1,954.0
	1 p. m. to 4 p. m....	762.3	+ .01	+ .6	− 3.2	173.8	102.9	862.6
	4 p. m. to 7 p. m....	709.5	+ .08	+ 4.8	− 6.9	173.3	102.6	810.0
	Total, 6 hours.	1,471.8	+ .09	+ 5.4	− 10.1	347.1	205.5	1,672.6

TABLE 116.—*Summary of calorimetric measurements, metabolism experiments Nos. 56–58 and 60–67, inclusive*—Continued.

Date.	Period.	(*a*) Heat measured in terms of C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b* × 60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total excess in outgoing air plus excess residual vapor.	(*f*) Heat rendered latent in vaporization of water, *e* × 0.592.	(*g*) Total heat determined, *a* + *c* + *d* + *f*.
	Experiment No. 63—Continued.							
1904.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 20–21..	7 p. m. to 10 p. m...	273.2	+0.01	+ 0.6	+ 3.1	155.8	92.2	369.1
	10 p. m. to 1 a. m...	241.2	....	....	....	162.0	95.9	337.1
	Total, 6 hours.	514.4	+ .01	+ 0.6	+ 3.1	317.8	188.1	706.2
	1 a. m. to 4 a. m....	201.9	− .01	− .6	....	153.5	90.9	292.2
	4 a. m. to 7 a. m....	169.7	+ .24	+14.4	....	155.0	91.7	275.8
	Total, 6 hours.	371.6	+ .23	+13.8	....	308.5	182.6	568.0
	Total, 1 day..	4,099.0	+ .25	+15.0	+ 7.5	1,316.4	779.3	4,900.8
Apr. 21–22..	7 a. m. to 10 a. m...	782.6	− .28	−16.8	− 9.9	175.8	104.0	859.9
	10 a. m. to 1 p. m...	823.5	− .04	− 2.4	+ 7.9	172.7	102.3	931.3
	Total, 6 hours.	1,606.1	− .32	−19.2	− 2.0	348.5	206.3	1,791.2
	1 p. m. to 4 p. m....	801.8	+ .01	+ 0.6	+ 4.6	186.4	110.3	917.3
	4 p. m. to 7 p. m....	721.6	+ .01	+ 0.6	+ 16.9	174.9	103.6	842.7
	Total, 6 hours.	1,523.4	+ .02	+ 1.2	+ 21.5	361.3	213.9	1,760.0
	7 p. m. to 10 p. m...	267.9	+ .06	+ 3.6	− 0.2	158.0	93.5	364.8
	10 p. m. to 1 a. m...	243.8	+ .01	+ 0.6	....	163.9	97.0	341.4
	Total, 6 hours.	511.7	+ .07	+ 4.2	− 0.2	321.9	190.5	706.2
	1 a. m. to 4 a. m....	207.5	− .01	− 0.6	....	128.6	76.2	283.1
	4 a. m. to 7 a. m....	194.3	....	....	....	148.3	87.8	282.1
	Total, 6 hours.	401.8	− .01	− 0.6	....	276.9	164.0	565.2
	Total, 1 day..	4,043.0	− .24	−14.4	+ 19.3	1,308.6	774.7	4,822.6
	Total, 3 days.	12,263.1	− .06	− 3.6	+ 70.2	3,953.5	2,340.4	14,670.1
	Experiment No. 64.							
Apr. 22–23..	7 a. m. to 10 a. m...	920.1	+ .03	+ 1.8	+ 10.6	194.2	115.0	1,047.5
	10 a. m. to 1 p. m...	883.1	− .11	− 6.6	+ 10.3	180.0	106.6	993.4
	Total, 6 hours.	1,803.2	− .08	− 4.8	+ 20.9	374.2	221.6	2,040.9
	1 p. m. to 4 p. m...	977.5	+ .32	+19.2	+ 28.3	192.7	114.0	1,139.0
	4 p. m. to 7 p. m....	905.7	− .25	−15.0	+ 3.7	180.9	107.1	1,001.5
	Total, 6 hours.	1,883.2	+ .07	+ 4.2	+ 32.0	373.6	221.1	2,140.5
	7 p. m. to 10 p. m...	971.5	+ .08	+ 4.8	+ 25.4	202.5	119.9	1,121.6
	10 p. m. to 1 a. m...	733.9	− .13	− 7.8	+ 18.2	190.4	112.7	857.0
	Total, 6 hours.	1,705.4	− .05	− 3.0	+ 43.6	392.9	232.6	1,978.6
	1 a. m. to 4 a. m....	564.3	+ .10	+ 6.0	+ 5.5	181.0	107.1	682.9
	4 a. m. to 7 a. m....	191.8	+ .06	+ 3.6	....	166.1	98.4	293.8
	Total, 6 hours.	756.1	+ .16	+ 9.6	+ 5.5	347.1	205.5	976.7
	Total, 1 day...	6,147.9	+ .10	+ 6.0	+102.0	1,487.8	880.8	7,136.7
	Experiment No. 65.							
Apr. 23–24..	7 a. m. to 10 a. m...	231.0	− .02	− 1.2	+ 11.7	162.5	96.2	337.7
	10 a. m. to 1 p. m..	197.5	− .05	− 3.0	+ 12.3	150.1	88.8	295.6
	Total, 6 hours.	428.5	− .07	− 4.2	+ 24.0	312.6	185.0	633.3

Table 116.—*Summary of calorimetric measurements, metabolism experiments Nos. 56–58 and 60–67, inclusive*—Continued.

Date.	Period.	(*a*) Heat measured in terms of C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b* × 60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total excess in outgoing air plus excess residual vapor.	(*f*) Heat rendered latent in vaporization of water, *e* × 0.592.	(*g*) Total heat determined, *a* + *c* + *d* + *f*.
	Experiment No. 65—Continued.							
1904.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 23–24..	1 p. m. to 4 p. m....	211.1	−0.18	−10.8	....	156.7	92.8	293.1
	4 p. m. to 7 p. m....	216.4	+ .15	+ 9.0	+ 23.5	147.9	87.6	336.5
	Total, 6 hours.	427.5	− .03	− 1.8	+ 23.5	304.6	180.4	629.6
	7 p. m. to 10 p. m...	242.5	....	....	....	160.7	95.1	337.6
	10 p. m. to 1 a. m...	245.9	+ .02	+ 1.2	....	162.4	96.1	343.2
	Total, 6 hours.	488.4	+ .02	+ 1.2	....	323.1	191.2	680.8
	1 a. m. to 4 a m....	174.8	− .04	− 2.4	....	149.9	88.8	261.2
	4 a. m. to 7 a. m....	163.0	+ .03	+ 1.8	....	141.2	83.6	248.4
	Total, 6 hours.	337.8	− .01	− 0.6	....	291.1	172.4	509.6
	Total, 1 day...	1,682.2	− .09	− 5.4	+ 47.5	1,231.4	729.0	2,453.3
	Experiment No. 66.							
Apr. 24–25..	7 a. m. to 10 a. m...	302.1	+ .03	+ 1.8	+ 8.7	150.6	89.2	401.8
	10 a. m. to 1 p. m...	265.8	....	....	− 0.1	139.8	82.8	348.5
	Total, 6 hours.	567.9	+ .03	+ 1.8	+ 8.6	290.4	172.0	750.3
	1 p. m. to 4 p. m....	241.9	+ .02	+ 1.2	+ 11.1	126.1	74.6	328.8
	4 p. m. to 7 p. m....	252.9	− .06	− 3.6	+ 13.5	128.0	75.8	338.6
	Total, 6 hours.	494.8	− .04	− 2.4	+ 24.6	254.1	150.4	667.4
	7 p. m. to 10 p. m...	224.5	+ .02	+ 1.2	+ 7.6	128.2	75.9	309.2
	10 p. m. to 1 a. m...	166.8	+ .02	+ 1.2	....	131.9	78.1	246.1
	Total, 6 hours.	391.3	+ .04	+ 2.4	+ 7.6	260.1	154.0	555.3
	1 a. m. to 4 a. m....	166.8	− .04	− 2.4	....	134.8	79.8	244.2
	4 a. m. to 7 a. m....	184.0	− .04	− 2.4	....	121.2	71.7	253.3
	Total, 6 hours.	350.8	− .08	− 4.8	....	256.0	151.5	497.5
	Total, 1 day...	1,804.8	− .05	− 3.0	+ 40.8	1,060.6	627.9	2,470.5
	Experiment No. 67.							
Apr. 25–26..	7 a. m. to 10 a. m...	345.4	+ .05	+ 3.0	+ 11.8	123.9	73.3	433.5
	10 a. m. to 1 p. m...	315.7	+ .03	+ 1.8	+ 11.8	121.5	72.0	401.3
	Total, 6 hours.	661.1	+ .08	+ 4.8	+ 23.6	245.4	145.3	834.8
	1 p. m. to 4 p. m....	290.8	− .04	− 2.4	+ 4.5	117.7	69.7	362.6
	4 p. m. to 7 p. m....	325.1	− .10	− 6.0	+ 6.8	121.1	71.7	397.6
	Total, 6 hours.	615.9	− .14	− 8.4	+ 11.3	238.8	141.4	760.2
	7 p. m. to 10 p. m...	248.1	+ .11	+ 6.6	....	114.2	67.6	322.3
	10 p. m. to 1 a. m...	201.6	+ .02	+ 1.2	....	128.0	75.8	278.6
	Total, 6 hours.	449.7	+ .13	+ 7.8	....	242.2	143.4	600.9
	1 a. m. to 4 a. m....	175.8	− .11	− 6.6	....	122.4	72.4	241.6
	4 a. m. to 7 a. m....	146.7	+ .10	+ 6.0	....	109.5	64.8	217.5
	Total, 6 hours.	322.5	− .01	− 0.6	....	231.9	137.2	459.1
	Total, 1 day...	2,049.2	+ .06	+ 3.6	+ 34.9	958.3	567.3	2,655.0
Apr. 26–27..	7 a. m. to 10 a. m...	377.1	+ .01	+ 0.6	+ 8.3	118.5	70.2	456.2
	10 a. m. to 1 p. m...	351.6	− .02	− 1.2	+ 0.2	119.1	70.5	421.1
	Total, 6 hours.	728.7	− .01	− 0.6	+ 8.5	237.6	140.7	877.3

Table 116.—*Summary of calorimetric measurements, metabolism experiments Nos. 56–58 and 60–67, inclusive*—Continued.

Date.	Period.	(*a*) Heat measured in terms of C_{20}.	(*b*) Change of temperature of calorimeter.	(*c*) Capacity correction of calorimeter, *b* × 60.	(*d*) Correction due to temperature of food and dishes.	(*e*) Water vaporized equals total excess in outgoing air plus excess residual vapor.	(*f*) Heat rendered latent in vaporization of water, *e* × 0.592.	(*g*) Total heat determined, *a* + *c* + *d* + *f*.
	Experiment No. 67—Continued.							
1904.		*Calories.*	*Degrees.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Apr. 26–27..	1 p. m. to 4 p. m....	356.7	+0.05	+ 3.0	+ 7.2	120.4	71.3	438.2
	4 p. m. to 7 p. m....	308.8	− .11	− 6.6	+ 14.5	113.2	67.0	383.7
	Total, 6 hours.	665.5	− .06	− 3.6	+ 21.7	233.6	138.3	821.9
	7 p. m. to 10 p. m...	233.9	+ .05	+ 3.0	+ 0.5	111.8	66.2	303.6
	10 p. m. to 1 a. m...	191.6	+ .14	+ 8.4	....	116.2	68.8	268.8
	Total, 6 hours.	425.5	+ .19	+11.4	+ 0.5	228.0	135.0	572.4
	1 a. m. to 4 a. m....	178.8	− .16	− 9.6	....	111.2	65.8	235.0
	4 a. m. to 7 a. m....	154.7	....	....	....	102.4	60.6	215.3
	Total, 6 hours.	333.5	− .16	− 9.6	....	213.6	126.4	450.3
	Total, 1 day...	2,153.2	− .04	− 2.4	+ 30.7	912.8	540.4	2,721.9
	Total, 2 days..	4,202.4	+ .02	+ 1.2	+ 65.6	1,871.1	1,107.7	5,376.9

TABLE 117.—*Total heat eliminated in 3-hour periods, metabolism experiments Nos. 56–58 and 60–67 inclusive.*

Kind and number of experiment.	Day.	7 a. m. to 10 a. m.	10 a. m. to 1 p. m.	Total, 6 hours.	1 p. m. to 4 p. m.	4 p. m. to 7 p. m.	Total, 6 hours.	7 p. m. to 10 p. m.	10 p. m. to 1 a. m.	Total, 6 hours.	1 a. m. to 4 a. m.	4 a. m. to 7 a. m.	Total, 6 hours.	Total, 1 day.
Rest experiments.		*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
No. 58	1			392. 26			543. 81			482. 23			400. 83	1, 819. 13
No. 58	2			563. 68			423. 96			434. 47			423. 40	1, 845. 51
No. 58	3			611. 13			527. 45			465. 69			442. 98	2, 047 25
Average per day				522. 36			498. 41			460. 80			422. 40	1, 903. 96
No. 60	1	355. 39	292. 56	647. 95	300. 99	293. 00	593. 99	325. 11	238. 87	563. 98	203. 12	204. 27	407. 39	2, 213. 31
No. 60	2	367. 70	303. 89	671. 59	302. 16	298. 20	600. 36	344. 97	218. 74	563. 71	184. 72	180. 55	365. 27	2, 200. 93
No. 60	3	376. 58	317. 04	693. 62	310. 04	317. 29	627. 33	338. 20	229. 44	567. 64	195. 00	185. 87	380. 87	2, 269. 46
Average per day		366. 56	304. 50	671. 05	304. 40	302. 83	607. 23	336. 09	229. 02	565. 11	194. 28	190. 23	384. 51	2, 227. 90
No. 65	1	337. 66	295. 65	633. 31	293. 10	336. 52	629. 62	337. 53	343. 25	680. 78	261. 17	248. 39	509. 56	2, 453. 27
No. 66	1	401. 76	348. 54	750. 30	328. 83	338. 59	667. 42	309. 19	246. 10	555. 29	244. 20	253. 33	497. 53	2, 470. 54
No. 67	1	433. 49	401. 26	834. 75	362. 63	397. 56	760. 19	322. 34	278. 56	600. 90	241. 66	217. 46	459. 12	2, 654. 96
No. 67	2	456. 20	421. 08	877. 28	438. 23	383. 75	821. 98	303. 61	268. 79	572. 40	235. 00	215. 27	450. 27	2, 721. 93
Average per day		444. 85	411. 17	856. 02	400. 43	390. 66	791. 09	312. 98	273. 68	586. 65	238. 33	216. 37	454. 70	2, 688. 45
Average per day, Nos. 65–67		407. 28	366. 63	773. 91	355. 70	364. 11	719. 80	318. 17	284. 18	602. 34	245. 51	233. 61	479. 12	2, 575. 18
Average rest experiments				667. 59			619. 61			548. 71			433. 72	2, 269. 63
Work experiments.														
No. 56	1			2, 003. 71			1, 985. 66			777. 86			527. 87	5, 295. 10
No. 56	2			2, 203. 00			1, 966. 14			737. 18			527. 09	5, 433. 41
No. 56	3			1, 852. 53			2, 011. 51			726. 28			533. 56	5, 123. 88
Average per day				2, 019. 75			1, 987. 77			747. 11			529. 51	5, 284. 13
No. 57	1			2, 225. 43			2, 120. 07			762. 17			474. 71	5, 582. 38
No. 57	2			1, 964. 40			2, 089. 83			820. 85			502. 64	5, 377. 72
No. 57	3			2, 486. 85			1, 649. 29			721. 04			486. 81	5, 343. 99
Average per day				2, 225. 56			1, 953. 06			768. 02			488. 05	5, 434. 70
No. 61	1	902. 50	1, 084. 51	1, 987. 01	790. 39	673. 16	1, 463. 55	361. 05	253. 61	614. 66	261. 68	238. 13	499. 81	4, 565. 03

No. 62	1	890. 52	932. 62	1,823. 14	877. 76	927. 80	1,805. 56	356. 29	331. 06	687. 35	257. 50	228. 75	486. 25	4,802. 30
No. 62	2	931. 11	955. 23	1,886. 34	852. 44	869. 07	1,721. 51	367. 91	317. 25	685. 16	266. 26	250. 49	516. 75	4,809. 76
No. 62	3	879. 78	979. 94	1,859. 72	944. 31	824. 19	1,768. 50	389. 35	308. 16	697. 51	275. 85	250. 73	526. 58	4,852. 31
Average per day		900. 47	955. 93	1,856. 40	891. 50	873. 69	1,765. 19	371. 18	318. 82	690. 01	266. 54	243. 32	509. 86	4,821. 46
No. 63	1	940. 11	946. 41	1,886. 52	960. 44	842. 71	1,803. 15	407. 26	315. 03	722. 29	275. 17	259. 61	534. 78	4,946. 74
No. 63	2	976. 22	977. 77	1,953. 99	862. 58	809. 94	1,672. 52	369. 10	337. 09	706. 19	292. 23	275. 84	568. 07	4,900. 77
No. 63	3	859. 94	931. 25	1,791. 19	917. 32	842. 68	1,760. 00	364. 82	341. 40	706. 22	283. 09	282. 08	565. 17	4,822. 58
Average per day		925. 42	951. 81	1,877. 23	913. 45	831. 78	1,745. 22	380. 39	331. 17	711. 57	283. 50	272. 51	556. 01	4,890. 03
No. 64	1	1,047. 53	993. 36	2,040. 89	1,139. 04	1,001. 53	2,140. 57	1,121. 56	856. 98	1,978. 54	682. 94	293. 76	976. 70	7,136. 70
Average work experiments				1,997. 48			1,854. 13			810. 24			551. 91	5,213. 76
Average rest and work experiments				1,443. 36			1,339. 75			701. 27			502. 66	3,987. 04

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67.*

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.*
EXPERIMENT NO. 56.						
First day.						
Income:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Oxygen from air	1,545.24				1,545.24	
Water in drink	1,950.00			218.20	1,731.80	
Water in food	2,935.50			328.48	2,607.02	
Solids in food	914.50	18.45	507.94	76.28	290.13	21.70
Total	7,345.24	18.45	507.94	622.96	6,174.19	21.70
Outgo:						
Water in feces	191.30			21.41	169.89	
Solids in feces	48.40	1.80	26.80	4.07	6.63	9.10
Water in urine	1,425.80			159.55	1,266.25	
Solids in urine	69.80	14.31	11.57	2.92	26.90	14.10
Water of respiration and perspiration	3,702.27	†.65		414.21	3,287.41	
CO_2 of respiration	1,775.61		484.25		1,291.36	
Total	7,213.18	16.76	522.62	602.16	6,048.44	23.20
Gain (+) or loss (−)	+ 132.06	+ 1.69	− 14.68	+ 20.80	+ 125.75	− 1.50
Ash of protein gained	.16					+ .16
	+ 132.22					− 1.34
Gains and losses of body material:						
Protein	+ 10.14	+ 1.69	+ 5.35	+ .71	+ 2.23	+ .16
Fat	+ 43.82		+ 33.35	+ 5.17	+ 5.30	
Glycogen	− 120.17		− 53.36	− 7.45	− 59.36	
Water	+ 199.93			+ 22.37	+ 177.56	
Ash	− 1.50					− 1.50
Total	+ 132.22	+ 1.69	− 14.66	+ 20.80	+ 125.73	− 1.34
Second day.						
Income:						
Oxygen from air	1,652.56				1,652.56	
Water in drink	1,950.00			218.20	1,731.80	
Water in food	2,970.10			332.35	2,637.75	
Solids in food	929.90	18.68	518.42	77.86	292.94	22.00
Total	7,502.56	18.68	518.42	628.41	6,315.05	22.00
Outgo:						
Water in feces	191.30			21.41	169.89	
Solids in feces	48.40	1.80	26.80	4.07	6.63	9.10
Water in urine	927.50			103.79	823.71	
Solids in urine	45.50	15.49	12.52	3.16	5.23	9.10
Water of respiration and perspiration	4,179.78	†.65		467.64	3,711.49	
CO_2 of respiration	1,813.56		494.60		1,318.96	
Total	7,206.04	17.94	533.92	600.07	6,035.91	18.20
Gain (+) or loss (−)	+ 296.50	+ .74	− 15.50	+ 28.34	+ 279.14	+ 3.80
Ash of protein gained	+ .07					+ .07
	+ 296.57					+ 3.87
Gains and losses of body material:						
Protein	+ 4.44	+ .74	+ 2.34	+ .31	+ .98	+ .07
Fat	− 68.04		− 51.78	− 8.03	− 8.23	
Glycogen	+ 76.52		+ 33.98	+ 4.74	+ 37.80	
Water	+ 279.87			+ 31.32	+ 248.55	
Ash	+ 3.80					+ 3.80
Total	+ 296.57	+ .74	− 15.46	+ 28.34	+ 279.10	+ 3.87
Third day.						
Income:						
Oxygen from air	1,517.80				1,517.80	
Water in drink	1,950.00			218.20	1,731.80	
Water in food	3,011.70			337.01	2,674.69	
Solids in food	948.30	18.95	531.00	79.76	296.19	22.40
Total	7,427.80	18.95	531.00	634.97	6,220.48	22.40

*Ash here considered an element.

† Nitrogen of perspiration.

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT NO. 56—Continued.						
Third day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	191.30	....	....	21.41	169.89	....
Solids in feces	48.40	1.80	26.80	4.07	6.63	9.10
Water in urine	914.30	....	....	102.31	811.99	....
Solids in urine	44.80	17.17	13.96	3.52	1.15	9.00
Water of respiration and perspiration	3,907.14	*.65	....	437.14	3,469.35	....
CO_2 of respiration	1,697.39	....	462.91	....	1,234.48	....
Total	6,803.33	19.62	503.67	568.45	5,693.49	18.10
Gain (+) or loss (−)	+ 624.47	− .67	+ 27.33	+ 66.52	+ 526.99	+ 4.30
Ash of protein lost	− .06	....	....	....	....	− .06
	+ 624.41	....	....	....	....	+ 4.24
Gains and losses of body material:						
Protein	− 4.02	− .67	− 2.12	− .28	− .89	− .06
Fat	+ 3.12	....	+ 2.37	+ .37	+ .38	....
Glycogen	+ 61.14	....	+ 27.14	+ 3.79	+ 30.21	....
Water	+ 559.87	....	....	+ 62.65	+ 497.22	....
Ash	+ 4.30	....	....	....	....	+ 4.30
Total	+ 624.41	− .67	+ 27.39	+ 66.53	+ 526.92	+ 4.24
Total, 3 days.						
Income:						
Oxygen from air	4,715.60	....	....	....	4,715.60	....
Water in drink	5,850.00	....	....	654.60	5,195.40	....
Water in food	8,917.30	....	....	997.84	7,919.46	....
Solids in food	2,792.70	56.08	1,557.36	233.90	879.26	66.10
Total	22,275.60	56.08	1,557.36	1,886.34	18,709.20	66.10
Outgo:						
Water in feces	573.90	....	....	64.23	509.67	....
Solids in feces	145.20	5.40	80.40	12.21	19.89	27.30
Water in urine	3,267.60	....	....	365.65	2,901.95	....
Solids in urine	160.10	46.97	38.05	9.60	33.28	32.20
Water of respiration and perspiration	11,789.19	*1.95	....	1,318.99	10,468.25	....
CO_2 of respiration	5,286.56	....	1,441.76	....	3,844.80	....
Total	21,222.55	54.32	1,560.21	1,770.68	17,777.84	59.50
Gain (+) or loss (−)	+1,053.05	+ 1.76	− 2.85	+ 115.66	+ 931.88	+ 6.60
Ash of protein gained	+ .17	....	....	....	....	+ .17
	+1,053.22	....	....	....	....	+ 6.77
Gains or losses of body material:						
Protein	+ 10.56	+ 1.76	+ 5.57	+ .74	+ 2.32	+ .17
Fat	− 21.10	....	− 16.06	− 2.49	− 2.55	....
Glycogen	+ 17.49	....	+ 7.76	+ 1.08	+ 8.65	....
Water	+1,039.67	....	....	+ 116.34	+ 923.33	....
Ash	+ 6.60	....	....	....	....	+ 6.60
Total	+1,053.22	+ 1.76	− 2.73	+ 115.67	+ 931.75	+ 6.77
EXPERIMENT NO. 57.						
First day.						
Income:						
Oxygen from air	1,608.76	....	....	....	1,608.76	....
Water in drink	2,291.00	....	....	256.36	2,034.64	....
Water in food	2,310.10	....	....	258.50	2,051.60	....
Solids in food	1,214.90	17.63	557.41	83.32	536.24	20.30
Total	7,424.76	17.63	557.41	598.18	6,231.24	20.30

* Nitrogen of perspiration.

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT No. 57—Continued.						
First day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	298.53			33.41	265.12	
Solids in feces	52.27	2.91	25.29	3.47	12.86	7.74
Water in urine	932.21			104.31	827.90	
Solids in urine	57.29	13.21	10.71	2.82	17.88	12.67
Water of respiration and perspiration	3,895.40	*.64		435.82	3,458.94	
CO_2 of respiration	2,092.88		570.79		1,522.09	
Total	7,328.58	16.76	606.79	579.83	6,104.79	20.41
Gain (+) or loss (−)	+ 96.18	+ .87	−49.38	+ 18.35	+126.45	− .11
Ash of protein gained	+ .08					+ .08
	+ 96.26					− .03
Gains or losses of body material:						
Protein	+ 5.22	+ .87	+ 2.76	+ .37	+ 1.14	+ .08
Fat	+ 21.07		+16.03	+ 2.49	+ 2.55	
Glycogen	− 153.47		−68.14	− 9.52	− 75.81	
Water	+ 223.55			+ 25.02	+198.53	
Ash	− .11					− .11
Total	+ 96.26	+ .87	−49.35	+ 18.36	+126.41	− .03
Second day.						
Income:						
Oxygen from air	1,562.83				1,562.83	
Water in drink	2,291.00			256.36	2,034.64	
Water in food	2,394.70			267.97	2,126.73	
Solids in food	1,215.30	18.23	556.70	83.18	536.39	20.80
Total	7,463.83	18.23	556.70	607.51	6,260.59	20.80
Outgo:						
Water in feces	298.53			33.41	265.12	
Solids in feces	52.27	2.91	25.29	3.47	12.86	7.74
Water in urine	789.10			88.30	700.80	
Solids in urine	48.50	14.99	12.16	3.20	7.43	10.72
Water of respiration and perspiration	4,192.11	*.64		469.03	3,722.44	
CO_2 of respiration	1,988.80		542.39		1,446.41	
Total	7,369.31	18.54	579.84	597.41	6,155.06	18.46
Gain (+) or loss (−)	+ 94.52	− .31	−23.14	+ 10.10	+105.53	+2.34
Ash of protein lost	− .03					− .03
	+ 94.49					+2.31
Gains or losses of body material:						
Protein	− 1.86	− .31	− .98	− .13	− .41	− .03
Fat	− 30.30		−23.06	− 3.58	− 3.66	
Glycogen	+ 2.08		+ .92	+ .13	+ 1.03	
Water	+ 122.23			+ 13.68	+108.55	
Ash	+ 2.34					+2.34
Total	+ 94.49	− .31	−23.12	+ 10.10	+105.51	+2.31
Third day.						
Income:						
Oxygen from air	1,556.79				1,556.79	
Water in drink	2,291.00			256.36	2,034.64	
Water in food	2,394.70			267.97	2,126.73	
Solids in food	1,215.30	18.23	556.70	83.18	536.39	20.80
Total	7,457.79	18.23	556.70	607.51	6,254.55	20.80

*Nitrogen of perspiration.

Table 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
Experiment No. 57—Continued.						
Third day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	298.53	....	....	33.41	265.12	....
Solids in feces	52.27	2.91	25.29	3.47	12.86	7.74
Water in urine	806.53	....	....	90.25	716.28	....
Solids in urine	49.57	15.80	12.82	3.37	6.62	10.96
Water of respiration and perspiration	4,033.42	*.64	....	451.27	3,581.51	....
CO_2 of respiration	1,953.01	....	532.63	....	1,420.38	....
Total	7,193.33	19.35	570.74	581.77	6,002.77	18.70
Gain (+) or loss (−)	+ 264.46	−1.12	−14.04	+ 25.74	+251.78	+2.10
Ash of protein lost	− .10	....	....	....	....	− .10
	+ 264.36	....	....	....	....	+2.00
Gains or losses of body material:						
Protein	− 6.72	−1.12	− 3.55	− .47	− 1.48	− .10
Fat	− 55.22	....	−42.02	− 6.52	− 6.68	....
Glycogen	+ 71.10	....	+31.57	+ 4.41	+ 35.12	....
Water	+ 253.10	....	....	+ 28.32	+224.78	....
Ash	+ 2.10	....	....	....	....	+2.10
Total	+ 264.36	−1.12	−14.00	+ 25.74	+251.74	+2.00
Total, 3 days.						
Income:						
Oxygen from air	4,728.38	....	....	....	4,728.38	....
Water in drink	6,873.00	....	....	769.08	6,103.92	....
Water in food	7,099.50	....	....	794.44	6,305.06	....
Solids in food	3,645.50	54.09	1,670.81	249.68	1,609.02	61.90
Total	22,346.38	54.09	1,670.81	1,813.20	18,746.38	61.90
Outgo:						
Water in feces	895.59	....	....	100.23	795.36	....
Solids in feces	156.81	8.73	75.87	10.41	38.58	23.22
Water in urine	2,527.84	....	....	282.86	2,244.98	....
Solids in urine	155.36	44.00	35.69	9.39	31.93	34.35
Water of respiration and perspiration	12,120.93	*1.92	....	1,356.12	10,762.89	....
CO_2 of respiration	6,034.69	....	1,645.81	....	4,388.88	....
Total	21,891.22	54.65	1,757.37	1,759.01	18,262.62	57.57
Gain (+) or loss (−)	+ 455.16	− .56	−86.56	+ 54.19	+483.76	+4.33
Ash of protein lost	− .05	....	....	....	....	− .05
	+ 455.11	....	....	....	....	+4.28
Gains or losses of body material:						
Protein	− 3.36	− .56	− 1.77	− .23	− .75	− .05
Fat	− 64.45	....	−49.05	− 7.61	− 7.79	....
Glycogen	− 80.29	....	−35.65	− 4.98	− 39.66	....
Water	+ 598.88	....	....	+ 67.02	+531.86	....
Ash	+ 4.33	....	....	....	....	+4.33
Total	+ 455.11	− .56	−86.47	+ 54.20	+483.66	+4.28
Experiment No. 58.						
First day.						
Income:						
Oxygen from air	528.50	....	....	....	528.50	....
Water in drink	400.00	....	....	44.76	355.24	....
Water in food	558.50	....	....	62.50	496.00	....
Solids in food	326.50	6.58	149.82	21.97	138.13	10.00
Total	1,813.50	6.58	149.82	129.23	1,517.87	10.00

* Nitrogen of perspiration.

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT NO. 58—Continued.						
First day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	34.77			3.89	30.88	
Solids in feces	13.57	0.40	6.28	.86	3.33	2.70
Water in urine	372.90			41.73	331.17	
Solids in urine	30.90	7.79	6.87	1.69	8.90	5.65
Water of respiration and perspiration	507.13			56.75	450.38	
CO_2 of respiration	628.07		171.29		456.78	
Total	1,587.34	8.19	184.44	104.92	1,281.44	8.35
Gain (+) or loss (−)	+226.16	−1.61	− 34.62	+24.31	+236.43	+1.65
Ash of protein lost	− .15					− .15
	+226.01					+1.50
Gains or losses of body material:						
Protein	− 9.66	− 1.61	− 5.10	− .68	− 2.12	− .15
Fat	− 49.24		− 37.47	− 5.81	− 5.96	
Glycogen	+ 17.99		+ 7.99	+ 1.11	+ 8.89	
Water	+265.26			+29.68	+235.58	
Ash	+ 1.65					+1.65
Total	+226.00	− 1.61	− 34.58	+24.30	+236.39	+1.50
Second day.						
Income:						
Oxygen from air	548.98				548.98	
Water in drink	400.00			44.76	355.24	
Water in food	536.80			60.07	476.73	
Solids in food	323.20	6.45	148.05	21.72	137.18	9.80
Total	1,808.98	6.45	148.05	126.55	1,518.13	9.80
Outgo:						
Water in feces	34.77			3.89	30.88	
Solids in feces	13.57	.40	6.28	.86	3.33	2.70
Water in urine	366.90			41.06	325.84	
Solids in urine	32.80	8.27	7.29	1.79	9.85	5.60
Water of respiration and perspiration	828.78			92.74	736.04	
CO_2 of respiration	644.54		175.80		468.74	
Total	1,921.36	8.67	189.37	140.34	1,574.68	8.30
Gain (+) or loss (−)	−112.38	− 2.22	− 41.32	−13.79	− 56.55	+1.50
Ash of protein lost	− .20					− .20
	112.58					+1.30
Gains or losses of body material:						
Protein	− 13.32	− 2.22	− 7.03	− .93	− 2.94	− .20
Fat	− 59.33		− 45.15	− 7.00	− 7.18	
Glycogen	+ 24.47		+ 10.86	+ 1.52	+ 12.09	
Water	− 65.91			− 7.38	− 58.53	
Ash	+ 1.50					+1.50
Total	−112.59	− 2.22	− 41.32	−13.79	− 56.56	+1.30
Third day.						
Income:						
Oxygen from air	589.13				589.13	
Water in drink	263.00			29.43	233.57	
Water in food	619.30			69.30	550.00	
Solids in food	335.70	6.95	154.75	22.68	140.72	10.60
Total	1,807.13	6.95	154.75	121.41	1,513.42	10.60

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT NO. 58—Continued.						
Third day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	34.77			3.89	30.88	
Solids in feces	13.57	0.40	6.28	.86	3.33	2.70
Water in urine	410.00			45.88	364.12	
Solids in urine	37.00	9.34	8.22	2.02	11.16	6.26
Water of respiration and perspiration	816.94			91.42	725.52	
CO_2 of respiration	706.27		192.61		513.66	
Total	2,018.55	9.74	207.11	144.07	1,648.67	8.96
Gain (+) or loss (−)	−211.42	− 2.79	− 52.36	−22.66	−135.25	+1.64
Ash of protein lost	− .26					− .26
	−211.68					+1.38
Gains or losses of body material:						
Protein	− 16.74	− 2.79	− 8.84	− 1.17	− 3.68	− .26
Fat	− 47.86		− 36.42	− 5.65	− 5.79	
Glycogen	− 16.00		− 7.10	− .99	− 7.91	
Water	−132.72			−14.85	−117.87	
Ash	+ 1.64					+1.64
Total	−211.68	− 2.79	− 52.36	−22.66	−135.25	+1.38
Total, 3 days.						
Income:						
Oxygen from air	1,666.61				1,666.61	
Water in drink	1,063.00			118.95	944.05	
Water in food	1,714.60			191.87	1,522.73	
Solids in food	985.40	19.98	452.62	66.37	416.03	30.40
Total	5,429.61	19.98	452.62	377.19	4,549.42	30.40
Outgo:						
Water in feces	104.31			11.67	92.64	
Solids in feces	40.71	1.20	18.84	2.58	9.99	8.10
Water in urine	1,149.80			128.67	1,021.13	
Solids in urine	100.70	25.40	22.38	5.50	29.91	17.51
Water of respiration and perspiration	2,152.85			240.91	1,911.94	
CO_2 of respiration	1,978.88		539.70		1,439.18	
Total	5,527.25	26.60	580.92	389.33	4,504.79	25.61
Gain (+) or loss (−)	− 97.64	− 6.62	−128.30	−12.14	+ 44.63	+4.79
Ash of protein lost	− .61					− .61
	− 98.25					+4.18
Gains or losses of body material:						
Protein	− 39.72	− 6.62	− 20.97	− 2.78	− 8.74	− .61
Fat	−156.43		−119.04	−18.46	− 18.93	
Glycogen	+ 26.46		+ 11.75	+ 1.64	+ 13.07	
Water	+ 66.63			+ 7.45	+ 59.18	
Ash	+ 4.79					+4.79
Total	− 98.27	− 6.62	−128.26	−12.15	+ 44.58	+4.18
EXPERIMENT NO. 60.						
First day.						
Income:						
Oxygen from air	623.41				623.41	
Water in drink	700.00			78.33	621.67	
Water in food	1,159.30			129.73	1,029.57	
Solids in food	526.70	16.33	250.07	36.27	207.83	16.20
Total	3,009.41	16.33	250.07	244.33	2,482.48	16.20

Table 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
Experiment No. 60—Continued.						
First day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	97.07			10.86	86.21	
Solids in feces	29.33	1.72	13.41	1.78	7.12	5.30
Water in urine	1,046.32			117.08	929.24	
Solids in urine	61.48	16.45	14.61	3.41	10.84	16.17
Water of respiration and perspiration	959.54			107.37	852.17	
CO_2 of respiration	770.68		210.20		560.48	
Total	2,964.42	18.17	238.22	240.50	2,446.06	21.47
Gain (+) or loss (−)	+ 44.99	− 1.84	+ 11.85	+ 3.83	+ 36.42	− 5.27
Ash of protein lost	− .17					− .17
	+ 44.82					− 5.44
Gains or losses of body material:						
Protein	− 11.04	− 1.84	− 5.83	− .77	− 2.43	− .17
Fat	− 2.73		− 2.08	− .32	− .33	
Glycogen	+ 44.50		+ 19.76	+ 2.76	+ 21.98	
Water	+ 19.36			+ 2.16	+ 17.20	
Ash	− 5.27					− 5.27
Total	+ 44.82	− 1.84	+ 11.85	+ 3.83	+ 36.42	− 5.44
Second day.						
Income:						
Oxygen from air	627.27				627.27	
Water in drink	700.00			78.33	621.67	
Water in food	1,054.80			118.03	936.77	
Solids in food	525.20	17.02	250.10	36.27	205.71	16.10
Total	2,907.27	17.02	250.10	232.63	2,391.42	16.10
Outgo:						
Water in feces	97.07			10.86	86.21	
Solids in feces	29.33	1.72	13.41	1.78	7.12	5.30
Water in urine	951.30			106.45	844.85	
Solids in urine	55.90	14.74	13.10	3.05	10.30	14.71
Water of respiration and perspiration	272.15			30.45	241.70	
CO_2 of respiration	761.43		207.65		553.78	
Total	2,167.18	16.46	234.16	152.59	1,743.96	20.01
Gain (+) or loss (−)	+740.09	+ .56	+ 15.94	+80.04	+647.46	− 3.91
Ash of protein gained	+ .05					+ .05
	+740.14					− 3.86
Gains or losses of body material:						
Protein	+ 3.36	+ .56	+ 1.77	+ .24	+ .74	+ .05
Fat	− 16.03		− 12.20	− 1.89	− 1.94	
Glycogen	+ 59.56		+ 26.45	+ 3.69	+ 29.42	
Water	+697.16			+78.01	+619.15	
Ash	− 3.91					− 3.91
Total	+740 14	+ 56	+ 16.02	+80.05	+647.37	− 3.86
Third day.						
Income:						
Oxygen from air	635.72				635.72	
Water in drink	700.00			78.33	621.67	
Water in food	1,054.80			118.03	936.77	
Solids in food	525.20	17 02	250.10	36.27	205.71	16.10
Total	2,915.72	17.02	250.10	232.63	2,399.87	16.10

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT NO. 60—Continued.						
Third day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	97.07	....	....	10.86	86.21	....
Solids in feces	29.33	1.72	13.41	1,78	7.12	5.30
Water in urine	1,298.88	....	....	145.34	1,153.54	....
Solids in urine	76.32	15.95	14.17	3.31	22.81	20.08
Water of respiration and perspiration	1,198.69		....	134.13	1,064.56	....
CO_2 of respiration	807.78	....	220.29	....	587.49	....
Total	3,508.07	17.67	247.87	295.42	2,921.73	25.38
Gain (+) or loss (−)	− 592.35	− .65	+ 2.23	− 62.79	− 521.86	− 9.28
Ash of protein lost	− .06	....	....	....	....	− .06
	− 592.41	....	....	....	....	− 9.34
Gains or losses of body material:						
Protein	− 3.90	− .65	− 2.06	− .27	− .86	− .06
Fat	+ 30.19	....	+ 22.98	+ 3.56	+ 3.65	....
Glycogen	− 42.25	....	− 18.76	− 2.62	− 20.87	....
Water	− 567.17	....	....	− 63.46	− 503.71	....
Ash	− 9.28	....	....	....	....	− 9.28
Total	− 592.41	− .65	+ 2.16	− 62.79	− 521.79	− 9.34
Total, 3 days.						
Income:						
Oxygen from air	1,886.40	....		....	1,886.40	....
Water in drink	2,100.00	....	....	234.99	1,865.01	....
Water in food	3,268.90	....	....	365.79	2,903.11	....
Solids in food	1,577.10	50.37	750.27	108.81	619.25	48.40
Total	8,832.40	50.37	750.27	709.59	7,273.77	48.40
Outgo:						
Water in feces	291.21	....	....	32.58	258.63	....
Solids in feces	87.99	5.16	40.23	5.34	21.36	15.90
Water in urine	3,296.50	....	....	368.87	2,927.63	....
Solids in urine	193.70	47.14	41.88	9.77	43.95	50.96
Water of respiration and perspiration	2,430.38		....	271.95	2,158.43	....
CO_2 of respiration	2,339.89	....	638.14	....	1,701.75	....
Total	8,639.67	52.30	720.25	688.51	7,111.75	66.86
Gain (+) or loss (−)	+ 192.73	− 1.93	+ 30.02	+ 21.08	+ 162.02	−18.46
Ash of protein lost	− .18	....	....	....	....	− .18
	+ 192.55	....	....	....	....	−18.64
Gains or losses of body material:						
Protein	− 11.58	− 1.93	− 6.12	− .80	− 2.55	− .18
Fat	+ 11.43	....	+ 8.70	+ 1.35	+ 1.38	....
Glycogen	+ 61.81		+ 27.45	+ 3.83	+ 30.53	....
Water	+ 149.35	....	....	+ 16.71	+ 132.64	....
Ash	− 18.46	....	....	....	....	−18.46
Total	+ 192.55	− 1.93	+ 30.03	+ 21.09	+ 162.00	−18.64
EXPERIMENT NO. 61.						
Income:						
Oxygen from air	1,309.09	....	....	....	1,309.09	....
Water in drink	1,834.00	....	....	205.22	1,628.78	....
Water in food	1,029.50	....	....	115.20	914.30	....
Solids in food	657.50	16.52	341.40	50.74	230.54	18.30
Total	4,830.09	16.52	341.40	371.16	4,082.71	18.30

Table 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(a) Total weight.	(b) Nitrogen.	(c) Carbon.	(d) Hydrogen.	(e) Oxygen.	(f) Ash.
Experiment No. 61—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	92.67			10.37	82.30	
Solids in feces	30.73	1.64	15.45	2.16	6.42	5.06
Water in urine	843.00			94.33	748.67	
Solids in urine	†62.79	*17.25	12.85	3.35	14.77	14.57
Water of respiration and perspiration	2,869.45			321.09	2,548.36	
CO_2 of respiration	1,599.63		436.25		1,163.38	
Total	5,498.27	18.89	464.55	431.30	4,563.90	19.63
Gain (+) or loss (−)	− 668.18	− 2.37	−123.15	− 60.14	− 481.19	− 1.33
Ash of protein lost	− .22					− .22
	− 668.40					− 1.55
Gains or losses of body material:						
Protein	− 14.22	− 2.37	− 7.51	− .99	− 3.13	− .22
Fat	+ 9.85		+ 7.50	+ 1.16	+ 1.19	
Glycogen	− 277.40		−123.17	− 17.20	− 137.03	
Water	− 385.30			− 43.12	− 342.18	
Ash	− 1.33					− 1.33
Total	− 668.40	− 2.37	−123.18	− 60.15	− 481.15	− 1.55
Experiment No. 62.						
First day.						
Income:						
Oxygen from air	1,371.67				1,371.67	
Water in drink	2,797.90			313.09	2,484.81	
Water in food	779.40			87.21	692.19	
Solids in food	969.60	16.86	454.91	68.65	409.88	19.30
Total	5,918.57	16.86	454.91	468.95	4,958.55	19.30
Outgo:						
Water in feces	151.60			16.96	134.64	
Solids in feces	47.33	2.31	21.52	2.76	11.97	8.77
Water in urine	490.50			54.89	435.61	
Solids in urine	49.70	14.57	11.83	2.79	13.60	6.91
Water of respiration and perspiration	3,415.85			382.23	3,033.62	
CO_2 of respiration	1,695.94		462.52		1,233.42	
Total	5,850.92	16.88	495.87	459.63	4,862.86	15.68
Gain (+) or loss (−)	+ 67.65	− .02	− 40.96	+ 9.32	+ 95.69	+ 3.62
Ash of protein						
	+ 67.65					
Gains or losses of body material:						
Protein	− .12	− .02	− .06	− .01	− .03	
Fat	+ 26.65		− 20.28	− 3.14	− 3.23	
Glycogen	− 46.37		− 20.59	− 2.87	− 22.91	
Water	+ 137.17			+ 15.35	+ 121.82	
Ash	− 3.62					+ 3.62
Total	+ 67.65	− .02	− 40.93	+ 9.33	+ 95.65	+ 3.62
Second day.						
Income:						
Oxygen from air	1,387.67				1,387.67	
Water in drink	2,879.10			322.17	2,556.93	
Water in food	674.10			75.43	598.67	
Solids in food	965.90	16.85	455.75	68.90	405.40	19.00
Total	5,906.77	16.85	455.75	466.50	4,948.67	19.00

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* Nitrogen of perspiration.

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EPPERIMENT NO. 62—Continued.						
Second day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	151.60			16.96	134.64	
Solids in feces	47.33	2.31	21.52	2.76	11.97	8.77
Water in urine	494.30			55.31	438.99	
Solids in urine	50.10	15.01	12.19	2.87	13.06	6.97
Water of respiration and perspiration	2,933.95			328.31	2,605.64	
CO_2 of respiration	1,724.42		470.32		1,254.10	
Total	5,401.70	17.32	504.03	406.21	4,458.40	15.74
Gain (+) or loss (−)	+ 505.07	− .47	− 48.28	+ 60.29	+490.27	+ 3.26
Ash of protein lost	− .04					− .04
	+ 505.03					+ 3.22
Gains or losses of body material:						
Protein	− 2.82	− .47	− 1.49	− .20	− .62	− .04
Fat	− 13.31		− 10.13	− 1.57	− 1.61	
Glycogen	− 82.39		− 36.58	− 5.11	− 40.70	
Water	+ 600.29			+ 67.17	+ 533.12	
Ash	+ 3.26					+ 3.26
Total	− 505.03	− .47	− 48.20	+ 60.29	+ 490.19	+ 3.22
Third day.						
Income:						
Oxygen from air	1,399.26				1,399.26	
Water in drink	2,900.00			324.51	2,575.49	
Water in food	591.10			66.14	524.96	
Solids in food	965.90	16.94	456.97	69.00	404.29	18.70
Total	5,856.26	16.94	456.97	459.65	4,904.00	18.70
Outgo:						
Water in feces	151.60			16.96	134.64	
Solids in feces	47.33	2.31	21.52	2.76	11.97	8.77
Water in urine	626.70			70.13	556.57	
Solids in urine	63.50	16.75	13.61	3.21	21.10	8.83
Water of respiration and perspiration	3,573.19			399.84	3,173.35	
CO_2 of respiration	1,702.02		464.20		1,237.82	
Total	6,164.34	19.06	499.33	492.90	5,135.45	17.60
Gain (+) or loss (−)	− 308.08	− 2.12	− 42.36	− 33.25	− 231.45	+ 1.10
Ash of protein lost	− .19					− .19
	− 308.27					+ .91
Gains or losses of body material:						
Protein	− 12.72	− 2.12	− 6.73	− .89	− 2.79	− .19
Fat	− 34.65		− 26.37	− 4.09	− 4.19	
Glycogen	− 20.92		− 9.29	− 1.30	− 10.33	
Water	− 241.08			− 26.98	− 214.10	
Ash	+ 1.10					+ 1.10
Total	− 308.27	− 2.12	− 42.39	− 33.26	− 231.41	+ .91
Total, 3 days.						
Income:						
Oxygen from air	4,158.60				4,158.60	
Water in drink	8,577.00			959.77	7,617.23	
Water in food	2,044.60			228.78	1,815.82	
Solids in food	2,901.40	50.65	1,367.63	206.55	1,219.57	57.00
Total	17,681.60	50.65	1,367.63	1,395.10	14,811.22	57.00

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT No. 62—Continued.						
Total, 3 days—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	454.80	....	....	50.88	403.92	....
Solids in feces	141.99	6.93	64.56	8.28	35.91	26.31
Water in urine	1,611.50	....	....	180.33	1,431.17	....
Solids in urine	163.30	46.33	37.63	8.87	47.76	22.71
Water of respiration and perspiration	9,922.99	....	....	1,110.38	8,812.61	....
CO_2 of respiration	5,122.38	....	1,397.04	....	3,725.34	....
Total	17,416.96	53.26	1,499.23	1,358.74	14,456.71	49.02
Gain (+) or loss (−)	+ 264.64	− 2.61	−131.60	+ 36.36	+ 354.51	+ 7.98
Ash of protein lost	− .23	....	....	....	....	− .23
	+ 264.41	....	....	....	....	+ 7.75
Gains or losses of body material:						
Protein	− 15.66	− 2.61	− 8.28	− 1.10	− 3.44	− .23
Fat	− 74.61	....	− 56.78	− 8.80	− 9.03	....
Glycogen	− 149.68	....	− 66.46	− 9.28	− 73.94	....
Water	+ 496.38	....	....	+ 55.54	+ 440.84	....
Ash	+ 7.98	....	....	....	....	+ 7.98
Total	+ 264.41	− 2.61	−131.52	+ 36.36	+ 354.43	+ 7.75
EXPERIMENT No. 63.						
First day.						
Income:						
Oxygen from air	1,408.89	....	....	....	1,408.89	....
Water in drink	2,478.60	....	....	277.36	2,201.24	....
Water in food	629.50	....	....	70.44	559.06	....
Solids in food	750.50	16.68	429.87	62.29	224.16	17.50
Total	5,267.49	16.68	429.87	410.09	4,393.35	17.50
Outgo:						
Water in feces	97.15	....	....	10.87	86.28	....
Solids in feces	35.75	1.01	18.03	2.70	5.50	8.51
Water in urine	913.45	....	....	102.22	811.23	....
Solids in urine	45.05	14.22	10.76	2.84	4.77	12.46
Water of respiration and perspiration	3,952.69	....	....	442.31	3,510.38	....
CO_3 of respiration	1,601.69	....	436.81	....	1,164.88	....
Total	6,645.78	15.23	465.60	560.94	5,583.04	20.97
Gain (+) or loss (−)	−1,378.29	+ 1.45	− 35.73	−150.85	−1,189.69	− 3.47
Ash of protein gained	+ .13	....	....	....	....	+ .13
	−1,378.16	....	....	....	....	− 3.34
Gains or losses of body material:						
Protein	+ 8.70	+ 1.45	+ 4.59	+ .61	+ 1.92	+ .13
Fat	− 13.35	....	− 10.16	− 1.58	− 1.61	....
Glycogen	− 68.28	....	− 30.32	− 4.23	− 33.73	....
Water	−1,301.75	....	....	−145.67	−1,156.08	....
Ash	− 3.47	....	....	....	....	− 3.47
Total	−1,378.15	+ 1.45	− 35.89	−150.87	−1,189.50	− 3.34
Second day.						
Income:						
Oxygen from air	1,454.00	....	....	....	1,454.00	....
Water in drink	2,200.70	....	....	246.26	1,954.44	....
Water in food	1,949.60	....	....	218.16	1,731.44	....
Solids in food	745.40	17.11	420.22	61.96	223.81	22.30
Total	6,349.70	17.11	420.22	526.38	5,363.69	22.30

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT NO. 63—Continued.						
Second day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	97.15			10.87	86.28	
Solids in feces	35.75	1.01	18.03	2.70	5.50	8.51
Water in urine	1,758.86			196.82	1,562.04	
Solids in urine	86.74	19.37	14.66	3.88	24.84	23.99
Water of respiration and perspiration	3,479.03			389.23	3,089.73	
CO_2 of respiration	1,580.87		431.15		1,149.72	
Total	7,038.40	20.38	463.84	603.57	5,918.11	32.50
Gain (+) or loss (−)	− 688.70	− 3.27	− 43.62	− 77.19	− 554.42	−10.20
Ash of protein lost	− .30					− .30
	− 689.00					−10.50
Gains or losses of body material:						
Protein	− 19.62	− 3.27	− 10.36	− 1.37	− 4.32	− .30
Fat	− 63.38		− 48.23	− 7.48	− 7.67	
Glycogen	+ 33.57		+ 14.91	+ 2.08	+ 16.58	
Water	− 629.37			− 70.43	− 558.94	
Ash	− 10.20					−10.20
Total	− 689.00	− 3.27	− 43.68	− 77.20	− 554.35	−10.50
Third day.						
Income:						
Oxygen from air	1,454.34				1,454.34	
Water in drink	1,731.80			193.79	1,538.01	
Water in food	2,420.10			270.81	2,149.29	
Solids in food	746.90	16.69	414.20	62.72	227.79	25.50
Total	6.353.14	16.69	414.20	527.32	5.369.43	25.50
Outgo:						
Water in feces	97.15			10.87	86.28	
Solids in feces	35.75	1.01	18.03	2.70	5.50	8.51
Water in urine	1,757.04			196.61	1,560.43	
Solids in urine	86.66	19.85	15.02	3.97	23.85	23.97
Water of respiration and perspiration	3,653.96			408.88	3,245.08	
CO_2 of respiration	1,578.43		430.48		1,147.95	
Total	7,208.99	20.86	463.53	623.03	6.069.09	32.48
Gain (+) or loss (−)	− 855.85	− 4.17	− 49.33	− 95.71	− 699.66	− 6.98
Ash of protein lost	− .38					− .38
	− 856.23					− 7.36
Gains or losses of body material:						
Protein	− 25.02	− 4.17	− 13.21	− 1.75	− 5.51	− .38
Fat	− 63.35		− 48.21	− 7.48	− 7.66	
Glycogen	+ 27.05		+ 12 01	+ 1.68	+ 13.36	
Water	− 787.93			− 88.17	− 699.76	
Ash	− 6.98					− 6.98
Total	− 856.23	− 4.17	− 49.41	− 95.72	− 699.57	− 7.36
Total, 3 days.						
Income:						
Oxygen from air	4,317.23				4,317.23	
Water in drink	6,411.10			717.41	5,693.69	
Water in food	4,999.20			559.41	4,439.79	
Solids in food	2,242.80	50.48	1,264.29	186.97	675.76	65.30
Total	17,970.33	50.48	1,264.29	1,463.79	15,126.47	65.30

Table 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT NO. 63—Continued.						
Total 3 days—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	291.45	....	....	32.61	258.84	....
Solids in feces	107.25	3.03	54.09	8.10	16.50	25.53
Water in urine	4,429.35	....	....	495.65	3,933.70	....
Solids in urine	218.45	53.44	40.44	10.69	53.46	60.42
Water of respiration and perspiration	11,085.68	....	....	1,240.49	9,845.19	....
CO₂ of respiration	4,760.99	....	1,298.44	....	3,462.55	....
Total	20,893.17	56.47	1,392.97	1,787.54	17,570.24	85.95
Gain (+) or loss (−)	−2,922.84	− 5.99	−128.68	− 323.75	−2,443.77	− 20.65
Ash of protein lost	− .55	....	....	....	....	− .55
	−2,923.39	....	....	....	....	− 21.20
Gains or losses of body material:						
Protein	− 35.94	− 5.99	− 18.98	− 2.51	− 7.91	− .55
Fat	− 140.08	....	−106.60	− 16.54	− 16.94	....
Glycogen	− 7.66	....	− 3.40	− .47	− 3.79	....
Water	−2,719.05	....	....	− 304.27	−2,414.78	....
Ash	− 20.65	....	....	....	....	− 20.65
Total	−2,923.38	− 5.99	−128.98	− 323.79	−2,443.42	− 21.20
EXPERIMENT NO. 64.						
Income:						
Oxygen from air	2,105.65	....	....	....	2,105.65	....
Water in drink	3,832.00	....	....	428.80	3,403.20	....
Water in food	2,897.50	....	....	324.23	2,573.27	....
Solids in food	847.30	19.11	474.94	72.63	252.52	28.10
Total	9,682.45	19.11	494.94	825.66	8,334.64	28.10
Outgo:						
Water in feces	97.15	....	....	10.87	86.28	....
Solids in feces	35.75	1.01	18.03	2.70	5.50	8.51
Water in urine	1,075.55	....	....	120.35	955.20	....
Solids in urine	60.55	15.68	11.70	3.29	17.16	12.72
Water of respiration and perspiration	5,939.67	....	....	664.65	5,275.02	....
CO₂ of respiration	2,344.01	....	639.27	....	1,704.74	....
Total	9,552.68	16.69	669.00	801.86	8,043.90	21.23
Gain (+) or loss (−)	+ 129.77	+ 2.42	−194.06	+ 23.80	+ 290.74	+ 6.87
Ash of protein gained	+ .22	....	....	....	....	+ .22
	+ 129.99	....	....	....	....	+ 7.09
Gains or losses of body material:						
Protein	+ 14.52	+ 2.42	+ 7.67	+ 1.02	+ 3.19	+ .22
Fat	− 131.26	....	− 99.89	− 15.49	− 15.88	....
Glycogen	− 229.15	....	−101.74	− 14.21	− 113.20	....
Water	+ 469.01	....	....	+ 52.48	+ 416.53	....
Ash	+ 6.87	....	....	....	....	+ 6.87
Total	+ 129.99	+ 2.42	−193.96	+ 23.80	+ 290.64	+ 7.09
EXPERIMENT NO. 65.						
Income:						
Oxygen from air	729.16	....	....	....	729.16	....
Water in drink	....	....	....	....	....	....
Water in food	2,255.51	....	....	252.39	2,003.12	....
Solids in food	538.99	15.40	235.88	34.26	230.15	23.30
Total	3,523.66	15.40	235.88	286.65	2,962.43	23.30

Table 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
Experiment No. 65—Continued.						
Outgo:	*Grams*	*Grams.*	*Grams.*	*Grams.*	*Grams*	*Grams.*
Water in feces	62.17			6.96	55.21	
Solids in feces	21.50	.85	8.13	1.10	3.56	7.86
Water in urine	1,020.64			114.21	906.43	
Solids in urine	62.96	24.02	16.00	4.17	8.58	10.19
Water of respiration and perspiration	1,072.46			120.01	952.45	
CO_2 of respiration	815.04		222.28		592.76	
Total	3,054.77	24.87	246.41	246.45	2,518.99	18.05
Gain (+) or loss (−)	+ 468.89	− 9.47	− 10.53	+ 40.20	+ 443.44	+ 5.25
Ash of protein lost	− .87					− .87
	+ 468.02					+ 4.38
Gains or losses of body material:						
Protein	− 56.82	− 9.47	− 30.00	− 3.98	− 12.50	− .87
Fat	− 128.39		− 97.70	− 15.15	− 15.54	
Glycogen	+ 264.05		+117.24	+ 16.37	+ 130.44	
Water	+ 383.93			+ 42.96	+ 340.97	
Ash	+ 5.25					+ 5.25
Total	+ 468.02	− 9.47	− 10.46	+ 40.20	+ 443.37	+ 4.38
Experiment No. 66.						
Income:						
Oxygen from air	707.00				707.00	
Water in drink						
Water in food	2,039.22			228.19	1,811.03	
Solids in food	461.48	14.11	205.93	29.63	192.71	19.10
Total	3,207.70	14.11	205.93	257.82	2,710.74	19.10
Outgo:						
Water in feces	62.17			6.96	55.21	
Solids in feces	21.50	.85	8.13	1.10	3.56	7.86
Water in urine	981.18			109.79	871.39	
Solids in urine	60.52	22.31	14.87	3.87	9.68	9.79
Water of respiration and perspiration	883.83			98.90	784.93	
CO_2 of respiration	839.74		229.03		610.71	
Total	2,848.94	23.16	252.03	220.62	2,335.48	17.65
Gain (+) or loss (−)	+ 358.76	− 9.05	− 46.10	+ 37.20	+ 375.26	+ 1.45
Ash of protein lost	− .83					− .83
	+ 357.93					+ .62
Gains or losses of body material:						
Protein	− 54.30	− 9.05	− 28.67	− 3.80	− 11.95	− .83
Fat	− 75.43		− 57.40	− 8.90	− 9.13	
Glycogen	+ 90.18		+ 40.04	+ 5.59	+ 44.55	
Water	+ 396.03			+ 44.32	+ 351.71	
Ash	+ 1.45					+ 1.45
Total	+ 357.93	− 9.05	− 46.03	+ 37.21	+ 375.18	+ 0.62
Experiment No 67.						
First day.						
Income:						
Oxygen from air	791.03				791.03	
Water in drink						
Water in food	1,581.24			176.94	1,404.30	
Solids in food	495.36	11.53	216.19	31.37	218.90	17.37
Total	2,967.63	11.53	216.19	208.31	2,414.23	17.37

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT NO. 67—Continued.						
First day—Continued.						
Outgo:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Water in feces	62.17			6.96	55.21	
Solids in feces	21.50	.85	8.13	1.10	3.56	7.86
Water in urine	1,013.77			113.44	900.33	
Solids in urine	62.53	18.45	12.29	3.20	18.47	10.12
Water of respiration and perspiration	842.28			94.25	748.03	
CO_2 of respiration	951.55		259.52		692.03	
Total	2,953.80	19.30	279.94	218.95	2,417.63	17.98
Gain (+) or loss (−)	− 86.17	− 7.77	− 63.75	− 10.64	− 3.40	− .61
Ash of protein lost	− .71					− .71
Total	− 86.88					− 1.32
Gains or losses of body material:						
Protein	− 46.62	− 7.77	− 24.62	− 3.26	− 10.26	− .71
Fat	− 80.06		− 60.92	− 9.45	− 9.69	
Glycogen	+ 49.13		+ 21.81	+ 3.05	+ 24.27	
Water	− 8.72			− .98	− 7.74	
Ash	− .61					− .61
Total	− 86.88	− 7.77	− 63.73	− 10.64	− 3.42	− 1.32
Second day.						
Income:						
Oxygen from air	797.87				797.87	
Water in drink						
Water in food	1,405.02			157.22	1,247.80	
Solids in food	475.78	10.51	208.50	30.22	210.74	15.81
Total	2,678.67	10.51	208.50	187.44	2,256.41	15.81
Outgo:						
Water in feces	62.17			6.96	55.21	
Solids in feces	21.50	.85	8.13	1.10	3.56	7.86
Water in urine	1,266.29			141.70	1,124.59	
Solids in urine	78.11	16.42	10.94	2.85	35.26	12.64
Water of respiration and perspiration	877.76			98.22	779.54	
CO_2 of respiration	952.08		259.64		692.44	
Total	3,257.91	17.27	278.71	250.83	2,690.60	20.50
Gain (+) or loss (−)	− 579.24	− 6.76	− 70.21	− 63.39	− 434.19	− 4.69
Ash of protein lost	− .62					− .62
	− 579.86					− 5.31
Gains or losses of body material:						
Protein	− 40.56	− 6.76	− 21.42	− 2.84	− 8.92	− .62
Fat	− 67.91		− 51.68	− 8.01	− 8.22	
Glycogen	+ 6.41		+ 2.85	+ .40	+ 3.16	
Water	− 473.11			− 52.94	− 420.17	
Ash	− 4.69					− 4.69
Total	− 579.86	− 6.76	− 70.25	− 63.39	− 434.15	− 5.31
Total, 2 days.						
Income:						
Oxygen from air	1,588.90				1,588.90	
Water in drink						
Water in food	2,986.26			334.16	2,652.10	
Solids in food	971.14	22.04	424.69	61.59	429.64	33.18
Total	5,546.30	22.04	424.69	395.75	4,670.64	33.18
Outgo:						
Water in feces	124.34			13.92	110.42	
Solids in feces	43.00	1.70	16.26	2.20	7.12	15.72
Water in urine	2,280.06			255.14	2,024.92	
Solids in urine	140.64	34.87	23.23	6.05	53.73	22.76

TABLE 118.—*Daily gains or losses of body materials, metabolism experiments Nos. 56–58 and 60–67*—Continued.

	(*a*) Total weight.	(*b*) Nitrogen.	(*c*) Carbon.	(*d*) Hydrogen.	(*e*) Oxygen.	(*f*) Ash.
EXPERIMENT No. 67—Continued.						
Total, 2 days—Continued.						
Outgo—Continued.						
Water of respiration and perspiration	*Grams.* 1,720.04	*Grams.*	*Grams.*	*Grams.* 192.47	*Grams.* 1,527.57	*Grams.*
CO_2 of respiration	1,903.63		519.16		1,384.47	
Total	6,211.71	36.57	558.65	469.78	5,108.23	38.48
Gain (+) or loss (−)	− 665.41	− 14.53	−133.96	− 74.03	− 437.59	− 5.30
Ash of protein lost	− 1.33					− 1.33
	− 666.74					− 6.63
Gains or losses of body material:						
Protein	− 87.18	− 14.53	− 46.04	− 6.10	− 19.24	− 1.33
Fat	− 147.97		−112.60	− 17.46	− 17.91	
Glycogen	+ 55.54		+ 24.66	+ 3.45	+ 27.43	
Water	− 481.83			− 53.92	− 427.91	
Ash	− 5.30					− 5.30
Total	− 666.74	− 14.53	−133.98	− 74.03	− 437.57	− 6.63

TABLE 119.—*Daily bodily gain or loss of nutrients and energy thereof, metabolism experiments Nos. 56–58 and 60–67.*

Number and day of experiment.	Nutrients gained (+) or lost (−).			Energy gained (+) or lost (−) from—		
	(*a*) Protein.	(*b*) Fat.	(*c*) Carbohydrates.	(*d*) Protein, *a*×5.65.	(*e*) Fat, *b*×9.54.	(*f*) Carbohydrates, *c*×4.19.
Experiment No. 56:	*Grams.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
First day	+10.14	+ 43.82	−120.17	+ 57	+ 418	− 504
Second day	+ 4.41	− 68.04	+ 76.52	+ 25	− 649	+ 321
Third day	− 4.02	+ 3.12	+ 61.14	− 23	+ 30	+ 256
Total, 3 days	+10.56	− 21.10	+ 17.49	+ 59	− 201	+ 73
Experiment No. 57:						
First day	+ 5.22	+ 21.07	−153.47	+ 29	+ 201	− 643
Second day	− 1.86	− 30.30	+ 2.08	− 10	− 289	+ 9
Third day	− 6.72	− 55.22	+ 71.00	− 38	− 527	+ 298
Total, 3 days	− 3.36	− 64.45	− 80.29	− 19	− 615	− 336
Experiment No. 58:						
First day	− 9.66	− 49.24	+ 17.99	− 55	− 469	+ 75
Second day	−13.32	− 59.33	+ 24.47	− 75	− 566	+ 103
Third day	−16.74	− 47.86	− 16.00	− 95	− 457	− 67
Total, 3 days	− 39.72	−156.43	+ 26.46	−225	−1,492	+ 111
Experiment No. 60:						
First day	−11.04	− 2.73	+ 44.50	− 62	− 26	+ 186
Second day	+ 3.36	− 16.03	+ 59.56	+ 19	− 153	+ 250
Third day	− 3.90	+ 30.19	− 42.25	− 22	+ 288	− 177
Total, 3 days	−11.58	+ 11.43	+ 61.81	− 65	+ 109	+ 259
Experiment No. 61, 1 day	−14.22	+ 9.85	−277.40	− 80	+ 94	−1,162
Experiment No. 62:						
First day	− .12	− 26.65	− 46.37	− 1	− 254	− 194
Second day	− 2.82	− 13.31	− 82.39	− 16	− 127	− 345
Third day	−12.72	− 34.65	− 20.92	− 72	− 331	− 88
Total, 3 days	−15.66	− 74.61	−149.68	− 89	− 712	− 627

Table 119.—*Daily bodily gain or loss of nutrients and energy thereof, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Number and day of experiment.	Nutrients gained (+) or lost (−).			Energy gained (+) or lost (−) from—		
	(*a*) Protein.	(*b*) Fat.	(*c*) Carbohydrates.	(*d*) Protein, *a*×5.65.	(*e*) Fat, *b*×9.54.	(*f*) Carbohydrates *c*×4.19.
Experiment No. 63:	*Grams.*	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
First day	+ 8.70	− 13.35	− 68.28	+ 49	− 127	− 286
Second day	−19.62	− 63.38	+ 33.57	−111	− 605	+ 141
Third day	−25.02	− 63.35	+ 27.05	−141	− 604	+ 113
Total, 3 days	−35.94	−140.08	− 7.66	−203	−1,336	− 32
Experiment No. 64, 1 day	+14.52	−131.26	−229.15	+ 82	−1,252	− 960
Experiment No. 65, 1 day	−56.82	−128.39	+264.05	−321	−1,225	+1,106
Experiment No. 66, 1 day	−54.30	− 75.43	+ 90.18	−307	− 720	+ 378
Experiment No. 67:						
First day	−46.62	− 80.06	+ 49.13	−263	− 763	+ 206
Second day	−40.56	− 67.91	+ 6.41	−229	− 648	+ 27
Total, 2 days	−87.18	−147.97	+ 55.54	−492	−1,411	+ 233

Table 120.—*Record of work done on the bicycle ergometer, metabolism experiments Nos. 56, 57, and 61–64.*

Date.	Time.	Duration of period.		Number of revolutions.	Heat equivalent of total work.
	Experiment No. 56.				
1903.		*Hours.*	*Min.*		*Calories.*
Apr. 27	8.14 a. m. to 10.14 a. m	2		8,173	190
	10.30 a. m. to 12.24 p. m	1	54	3,779	88
	2 p. m. to 6 p. m	4		12,494	291
	Total	7	54	24,446	569
Apr. 28	8.15 a. m. to 12.30 p. m	4	15	14,477	336
	2 p. m. to 5.30 p. m	3	30	11,359	265
	Total	7	45	25,836	601
Apr. 29	8.15 a. m. to 11.24 a. m	3	9	10,720	250
	2 p. m. to 5.30 p. m	3	30	12,372	288
	Total	6	39	23,092	538
	Total, 3 days	22	18	73,374	1,708
	Experiment No. 57.				
May 7	8.15 a. m. to 10.02 a. m	1	47	6,527	152
	10.17 a. m. to 12.31 p. m	2	14	8,384	195
	2.30 p. m. to 4 p. m	1	30	5,817	136
	4.15 p. m. to 6.13 p. m	2		7,484	174
	Total	7	31	28,212	657
May 8	8.15 a. m. to 9.29 a. m	1	14	4,515	105
	10.08 a. m. to 11.23 a. m	1	15	6,027	140
	2.21 p. m. to 4 p. m	1	39	6,209	145
	4.15 p. m. to 6.15 p. m	2		7,405	173
	Total	6	8	24,156	563
May 9	8.15 a. m. to 10 a. m	1	45	7,412	173
	10.12 a. m. to 12.23 p. m	2	11	9,314	217
	2.06 p. m. to 4.02 p. m	1	56	7,526	175
	4.14 p. m. to 4.31 p. m		17	960	22
	Total	6	9	25,212	587
	Total, 3 days	19	48	77,580	1,807

Table 120.—*Record of work done on the bicycle ergometer, metabolism experiments Nos. 56, 57, and 61-64*—Continued.

Date.	Time.	Duration of period.		Number of revolutions.	Heat equivalent of total work.
	Experiment No. 61.				
1904.		*Hours.*	*Min.*		*Calories.*
Jan. 30	8.28 a. m. to 10.02 a. m	1	34	5,481	128
	10.15 a. m. to 11.24 a. m.; 11.48 a. m. to 12.31 p. m	1	52	6,426	150
	2.04 p. m. to 2.40 p. m.; 2.56 p. m. to 3.42 p. m.; 4.10 p. m. to 5 p. m	2	12	6,039	141
	Total, 1 day	5	38	17,946	419
	Experiment No. 62.				
Apr. 16	8.30 a. m. to 10 a. m	1	30	4,939	115
	10.31 a. m. to 12.01 p. m	1	30	4,939	115
	2.03 p. m. to 3.32 p. m	1	29	4,884	114
	4.06 p. m. to 5.36 p. m	1	30	4,938	115
	Total	5	59	19,700	459
Apr. 17	8.30 a. m. to 10 a. m	1	30	5,169	120
	10.30 a. m. to 12 noon	1	30	5,169	120
	2.01 p. m. to 2.24 p. m		23	1,321	31
	2.27 p. m. to 2.29 p. m		2	115	3
	2.42 p. m. to 3.33 p. m		51	2,929	68
	4.06 p. m. to 5.33 p. m	1	27	4,997	116
	Total	5	43	19,700	458
Apr. 18	8.30 a. m. to 8.33 a. m		3	166	4
	8.34 a. m. to 10 a. m	1	26	4,746	111
	10.30 a. m. to 12 noon	1	30	4,966	116
	2 p. m. to 3.30 p. m	1	30	4,966	116
	4.07 p. m. to 5.35 p. m	1	28	4,856	113
	Total	5	57	19,700	460
	Total, 3 days	17	39	59,100	1,377
	Experiment No. 63.				
Apr. 19	8.30 a. m. to 10 a. m	1	30	5,308	124
	10.30 a. m. to 12 noon	1	30	5,308	124
	2.01 p. m. to 3.31 p. m	1	30	5,309	124
	4.10 p. m. to 5.14 p. m	1	4	3,775	88
	Total	5	34	19,700	460
Apr. 20	8.31 a. m. to 10.01 a. m	1	30	5,184	121
	10.30 a. m. to 12 noon	1	30	5,184	121
	2 p. m. to 3.30 p. m	1	30	5,184	121
	4.07 p. m. to 5.19 p. m	1	12	4,148	97
	Total	5	42	19,700	460
Apr. 21	8.30 a. m. to 10.01 a. m	1	31	5,227	122
	10.31 a. m. to 12.01 p. m	1	30	5,169	120
	2 p. m. to 3.30 p. m	1	30	5,169	120
	4.07 p. m. to 5.19 p. m	1	12	4,135	96
	Total	5	43	19,700	458
	Total, 3 days	16	59	59,100	1,378
	Experiment No. 64.				
Apr. 22	8.01 a. m. to 10.01 a. m	2	00	7,455	174
	10.31 a. m. to 12 noon	1	29	5,529	129
	1.30 p. m. to 3.30 p. m	2	00	7,455	174
	4.29 p. m. to 6 p. m	1	31	5,653	132
	7.12 p. m. to 8.31 p. m	1	19	4,908	114
	9.16 p. m. to 10.16 p. m	1	00	3,727	87
	11.01 p. m. to 11.45 p. m		44	2,733	64
	1.03 a. m. to 1.31 a. m		28	1,739	41
	2.32 a. m. to 3.01 a. m		29	1,801	42
	Total	11	00	41,000	957

Table 121.—*Record of drinking water consumed by subjects in metabolism experiments Nos. 56–58 and 60–67.*

Experiment No.	Subject.	Kind of experiment.	Duration.	Drinking water consumed.			
				First day.	Second day.	Third day.	Total.
			Days.	*Cc.*	*Cc.*	*Cc.*	*Cc.*
56	J. C. W	Work, fat diet	3	1,950.0	1,950.0	1,950.0	5,850.0
57	do	Work, carbohydrate diet	3	2,291.0	2,291.0	2,291.0	6,873.0
58	H. F	Rest, carbohydrate diet	3	400.0	400.0	263.0	1,063.0
60	B. F. D	do	3	700.0	700.0	700.0	2,100.0
61	do	Work, carbohydrate diet	1	1,834.0	....		1,834.0
62	A. L. L	do	3	2,797.9	2,879.1	2,900.0	8,577.0
63	do	Work, fat diet	3	2,478.6	2,200.7	1,731.8	6,411.1
64	do	Severe work, fat diet	1	3,832.0	....	....	3.832.0
65	do	Rest, carbohydrate diet	1	None.	....	....	None.
66	do	do	1	do	....	....	Do.
67	do	do	2	do	None	....	Do.

Table 122.—*Body weight, pulse rate, and temperatures as recorded by the subject, metabolism experiments Nos. 56–58 and 60–67.*

Time.	Weight in underclothes.	Pulse rate.	Temperature.
1903.			
Experiment No. 56.	*Kg.*		*° C.*
Apr. 27, 7 a. m	76.38	62	36.83
1 p. m		75	37.50
7 p. m	77.09		
Apr. 28, 7 a. m	76.10	64	36.28
7 p. m	77.04		
Apr. 29, 7 a. m	76.23	66	36.67
7 p. m	77.65		
Apr. 30, 7 a. m	76.85	66	36.56
Experiment No. 57.			
May 7, 7 a. m	77.86	64	36.67
4 p. m			37.78
7 p. m	78.17		37.56
10 p. m			37.11
May 8, 7 a. m	77.68	66	36.83
10 a. m			37.17
1 p. m			37.17
7 p. m	78.56		37.33
10 p. m			37.11
May 9, 7 a. m	77.89	67	36.72
10 a. m			37.72
4 p. m			37.78
7 p. m	78.86		37.11
10 p. m			37.00
May 10, 7 a. m	78.12	65	36.67
Experiment No. 58.			
Nov. 10, 7 a. m			36.71
10 a. m			36.74
1 p. m			36.98
4 p. m	72.30		37.07
7 p. m	72.50		36.94
10 p. m			37.17
Nov. 11, 1 a. m			36.99
4 a. m			36.98
7 a. m			36.29
10 a. m			37.23
1 p. m	72.44		37.14
4 p. m			37.55
7 p. m	72.55		37.83
10 p. m	72.66		37.93
Nov. 12, 1 a. m			37.90
4 a. m			37.57
7 a. m	72.15		37.67
10 a. m			37.54
1 p. m			37.80
4 p. m			37.69
1903.			
Experiment No. 58—Continued.	*Kg.*		*° C.*
Nov. 12, 7 p. m	72.78		38.23
10 p. m	72.65		37.90
Nov. 13, 1 a. m			37.88
4 a. m			37.72
7 a. m	72.36		37.81
1904.			
Experiment No. 60.			
Jan. 27, 7 a. m	67.34	48	36.50
10 a. m		53	36.78
1 p. m		52	36.56
4 p. m		51	36.44
7 p. m	[a] 70.18		36.00
10 p. m			36.28
Jan. 28, 1 a. m			36.11
4 a. m			36.22
7 a. m	67.18	58	36.72
10 a. m		53	36.67
1 p. m		52	36.56
4 p. m			36.56
7 p. m	[a] 68.94		36.61
10 p. m		45	36.50
Jan. 29, 1 a. m			36.11
4 a. m			36.22
7 a. m	67.43	55	36.61
10 a. m			36.72
1 p. m			36.67
4 p. m		55	36.61
7 p. m	[a] 70.17		36.94
10 p. m			36.67
Jan. 30, 1 a. m		49	36.28
4 a. m			36.28
7 a. m	67.59	61	36.67
Experiment No. 61.			
		94	
Jan. 30, 5 p. m			
7 p. m	[a] 69.04		
Jan. 31, 7 a. m	66.25		
Experiment No. 62.			
Apr. 16, 7 a. m	75.58		
10 a. m			
1 p. m			
4 p. m			

[a] Clothes.

Table 122.—*Body weight, pulse rate, and temperatures as recorded by the subject, metabolism experiments Nos. 56–58 and 60–67*—Continued.

Time.	Weight in underclothes.	Pulse rate.	Temperature.
1904.			
Experiment No. 62—Continued.	*Kg.*		°*C.*
Apr. 16, 7 p. m.			
10 p. m.			
Apr. 17, 7 a. m.			
10 a. m.	75.96		37.83
1 p. m.			37.06
4 p. m.			37.67
7 p. m.		72	37.39
Apr. 18, 7 a. m.	75.94		37.33
10 a. m.			38.06
1 p. m.			37.17
4 p. m.			37.39
7 p. m.			37.39
10 p. m.			37.28
Experiment No. 63.			
Apr. 19, 7 a. m.	75.77		37.44
10 a. m.			38.17
1 p. m.			37.28
4 p. m.			37.72
7 p. m.			37.39
10 p. m.			37.56
Apr. 20, 7 a. m.	74.83		37.72
10 a. m.			37.83
1 p. m.			37.50
4 p. m.			37.72
7 p. m.			37.33
10 p. m.			37.50
Apr. 21, 7 a. m.	74.00		37.61
10 a. m.			37.94
1 p. m.			37.44
4 p. m.			38.17
7 p. m.			37.56
10 p. m.			37.50
1904.			
Experiment No. 64.	*Kg.*		°*C.*
Apr. 22, 7 a. m.	73.04		37.67
10 a. m.			38.78
1 p. m.			37.56
4 p. m.			38.00
10 p. m.			39.11
Experiment No. 65.			
Apr. 23, 7 a. m.	72.67		37.78
1 p. m.			37.44
4 p. m.			
7 p. m.			37.28
10 p. m.			37.33
Experiment No. 66.			
Apr. 24, 7 a. m.	73.04		37.39
10 a. m.			37.00
4 p. m.			37.06
7 p. m.			36.78
10 p. m.			36.89
Experiment No. 67			
Apr. 25, 7 a. m.	73.50		37.00
10 a. m.			37.17
1 p. m.			37.00
4 p. m.			37.39
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